Yaudheya Coin, 200 BC

In recognition of the uniqueness and antiquity of the Yaudheya coins the Department of Posts, Government of India, released a stamp of a denomination of Rs.2.00 and named it the Yaudheya Coin, 200 BC, on the eve of the Festival of India on 7th June 1985. The first day cover of this stamp finds a place in the display in the gallery. The stamp depicts a copper coin of the Yaudheya dynasty from 200 B.C. that symbolizes *Ahimsa*. The coin, whose obverse is seen on the stamp, is a numismatic rarity. Issued by the Yaudheya tribal republic of 200 BC, the coin is rich in the symbology so typical of those times. The deer represents the gentle and compassionate doctrine of "Ahimsa", the philosophy of Buddha, which held all life to be sacred. Above the deer appears the *"Kalash"*, the pot of plenty: and above the pot, the symbol of "Shri", goddess of good fortune and wellbeing. The reverse depicts the Republic's Deity, *Karthikeya*, the second son of Lord Shiva and His Consort Parvati[18].

Glass Technology

It was generally believed, based on the archeological findings from Arikemedu and some other south Indian sites, that glass and glass technology came to India from the Rome in the early centuries of the Christian era. However this belief has now largely been laid to rest by recent findings. Although the knowledge of use and manufacture of glass in India is much later than in some other parts of the world, the art of manufacturing glass attained a high degree of technological perfection in ancient India. The archeological excavations from different sites in India have revealed various glasses and glass like objects used mainly for the ornamental purposes and from this it is established that glass manufacturing began in India in the first quarter of the first millennium BC[19]. The earliest specimens of glass have been found from period II of Rupar, Hastinapur and Alamgirpur which date back to 1000 BC. The glass specimens unearthed include, beads, bangles, vessels, tiles and other miscellaneous objects. Mention of glass *(Kaca)* also occurs in early Sanskrit and Buddhist literature such as *Satapata Brahmana* (1000 BC) and *Vinaya Pitaka*[20]. A number of glass objects have been found at Maski in south India (1000-900 BC), Hastinapur and Taxila (1000-200 BC). Glass slag has also been found at Kolhapur, Nevasa, Paunar and Maheshwar. In this period glass and glazes were coloured by the addition of metal oxides[21] which acted as the colouring agent. Other ancient texts that mention use of glass in ancient India include the texts of *Ramayana*, *Brhatsamhita*, Kautilya's *Arthasashtra* and *Sukranitisara*.

The recent archeological excavations by Alok Kanungo of Deccan College, Pune have revealed the presence of a traditional glass factory at Kopia in Basti district of Uttar Pradesh. A large number of glass objects have been found at Kopia during the excavation and these finds point towards a definite presence of a large size glass manufacturing units/ industry at Kopia during the third century BC to third century AD. Blocks of glass, weighing more than 50 kg and measuring 45 cm x 30 cm x 23 cm have also been found at the site. These findings probably give an indication about the massive scale of glass manufacturing operations that was in vogue at Kopia during this period[22].

Most of the early evidence for glass has been in the form of glass beads. In India, glass is reported from about 200 archaeological sites starting from the early Iron Age period, with the exception of four beads from the Chalcolithic site of Maski[23]. There has been much discussion on ancient India being the leading bead (both stone and glass) exporter to the world at large. Interestingly, India enjoys much the same position even today. Indian glassmakers had well developed technological skills in the manufacture of beads, bangles and a few other glass articles. From the observation of various glass objects excavated at different sites, it may be inferred that Indian glassmakers employed methods such as moulding, folding, twisting and double-stripping. Perhaps, a method known as wire-winding was also adopted for preparing beads of various types[24]. The exhibit on Glass in the gallery mainly consists of a scaled down model of an ancient glass furnace with supporting visuals that shows the ancient glass map of India. There is also a display of variety of special tools that were used in the glass manufacture. The model of the glass furnace is made from the solitary reference of the ancient Indian glass furnace that comes from Nevasa, where a glass making kiln dated 3rd to 4th century AD was unearthed. The furnace was circular oven in shape and 2'6" in diameter and 1'7" depth and was made of burnt clay. Most of glass furnaces in ancient India were of open fired type, which used solid fuel and the melting was carried out in a clay pot.

Tipu's Rockets

In recognition of the unique Indian contributions in the field of Rocketry the gallery has on display an exhibit on Tipu's Rockets. The name "Rocket" comes from the Italian "Rocchetta", meaning "little fuse", a name of a small firecracker created by the Italian artificer Muratori in 1379[25]. India finds a special mention in the use of Rockets in the battlefield by the British. Rockets, or "fire-arrows" in some form or the other, have been known for a long time. From historical records it is now fairly well established that the Chinese were the first to use rockets some time during 1232 A.D[26, 27].

With the advent of the Cannons and their improvement as a powerful tool in warfare, during the 14th and 15th century, the rockets went into oblivion. The rockets reemerged as effective ammunition in battlefield during the second half of the 18th century in India. Hyder Ali and his famous son Tipu Sultan effectively used the rockets against the British army during the 18th century. The use of innovatively designed rockets by the army of Tipu Sultan against the British, in the famous battle of Pollilur (1780) in which the British were defeated provides a spectacular evidence of supremacy of the rockets in the battle and this has been chronicled in Indo-British technological history[28]. The rockets used by the Tipu Sultan's army were much more advanced than what the British had ever seen or known. The superiority in rockets were attained mainly by use of iron tubes for holding the propellant which enabled higher bursting pressures in the combustion chamber resulting in higher thrust and longer range for the missile. The rockets consisted of a tube about 60 mm diameter and 200 mm long fastened to a sword or 3 m bamboo pole, and had a range of 1-2 km[29]. The famous battle of Pollilur, (1780) in which the British were defeated, is depicted in a painting scene shown on the walls of Darya Daulat Bagh in Srirangapatna[30].

The British having witnessed a decisive power of the Indian rockets took an active interest in the rocket technology that they encountered during their Srirangapatna battle and developed it further during the 19th century. Several of these rockets were sent to England, and after thoroughly examining the Indian specimens, William Congreve son of the Comptroller of the Royal Arsenal, Woolwich, London, carried out an extensive research and development programme at the Arsenal's laboratory for improving the Indian rockets[31]. Congreve prepared a new propellant mixture, and developed a rocket motor with a strong iron tube with conical nose, weighing about 32 pounds (14.5 kilograms). The improved version of the solid fuel rockets designed by Congreve was first demonstrated by the Royal Arsenal in 1805. These improved rockets were effectively used by the British during the Napoleonic Wars and the War of 1812. These improved rockets were then used in the military throughout Europe.

Architecture

India has a rich tradition of architecture and the existence of this tradition is evident from the examples of architectural excellence of various eras that are visible even today and also through the presence of architectural literature of different geographic locations and ages[32].

Temple Architecture

Ageless enduring beauty of rich Indian heritage and culture is embodied in the temple architectures that depict outstanding sculptures which are evidently visible in ancient and medieval temples present all across the Indian sub continent. The skill and mastery craftsmanship of the unsung architects and workers who painstakingly designed and carved out these architectural beauties reveal unique styles that are expressed with such unbroken continuity to display the spirit of the Indian Culture. Art formed the central theme of these architectural masterpieces since ancient times and almost always every monument contained an element of religious reference[33]. Every style of building construction portrays a distinctive basic principle that symbolizes a particular culture and era. In this context the Indian Hindu temple architecture, the Nagara – or the North Indian style temples and Dravidian or the South Indian style temples are not only the abode of God and place of worship, but they are also the cradle of knowledge, art, architecture and culture. The design and construction of these temples synthesize the art, geometry and structural aspects in to a finely blend architectural marvel[34, 35].

In recognition of this unique Indian contribution to architecture a large section has been dedicated to the Indian architecture in the gallery and the presentation depicts the outstanding contributions of ancient and medieval India in the field of art and architecture. One of the most enduring architectures of India that has the world take notice of is evidenced in the characteristics of the Buddhist / Mauryan architecture. *Stupas* and Rock cut cave temples are the prime examples of the Mauryan architecture style and these structures largely displaced the extant use of terracotta and wood as sculptural medium with that of the stones.

The architecture section of the gallery begins with a specially created artistically elegant entry. Early Buddhist art has no finer expression than these *toranas* (entry gates) that surround the great stupa. Carvings of inspired intensity and imagery that depict the tenets of Buddhist art are depicted in these *toranas*. Visitors entering through this gate like structure are encountered with a series of exhibits that have been housed in a typical architectural style in which each of the models and exhibits are housed. These models and exhibits showcase different architectural styles from ancient and medieval India found across the Indian subcontinent. The first exhibit represents the architectural styles of the Mauryan period mostly representing the Buddhist style of architecture. A scaled down model of a Sanchi Stupa is presented in the exhibit and is amply supported with visually rich information on the architectural styles of the Buddhist era. Sanchi Stupa is the oldest stone structure in India and is 36.5 metres in diameter and 16.4 meters in height and built in a hemispherical dome, this stupa stands in eternal majesty with the paved path surrounding the stupa worn down by pilgrims over the centuries. The next exhibit is housed in a structure representing the rock art caves symbolized by the famous rock cut cave temple of Kailashnath temple found at Ellora. Models of different styles of temples and their plans and so also the material and construction methods used in building these temples have been duly illustrated in the visual information that supplements the exhibit. A specially designed touch screen multimedia computer is used in the exhibit that blends well with the structure and the contents of the multimedia would more than satisfy the serious visitor's urge for detailed information on the subject.

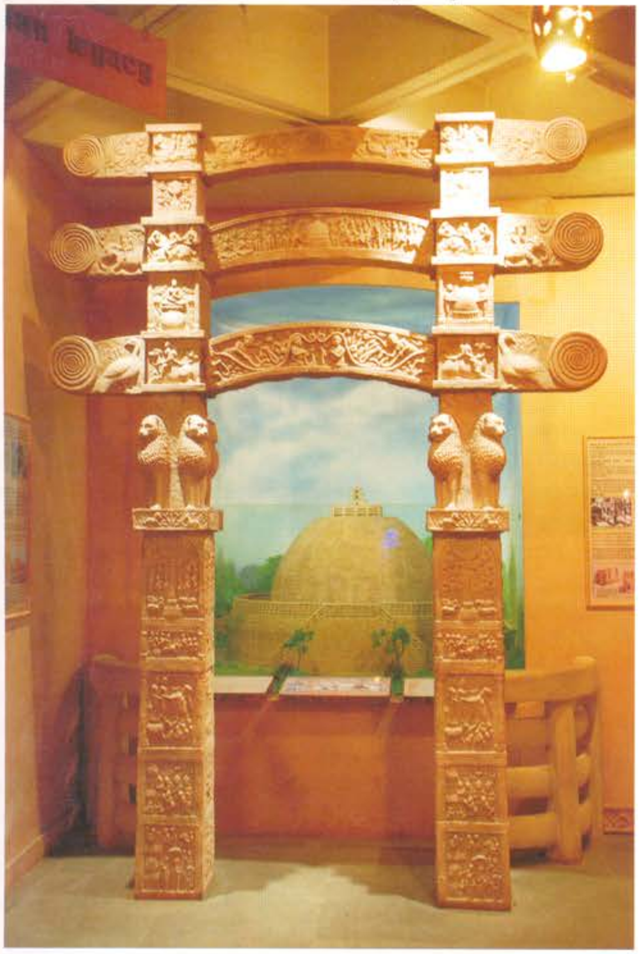

Fig. 4. Replica of Sanchi Stupa and its *torana*.

The typical form and style of the Hindu temples were mostly created during 600-800 AD in southern India starting with the *Chalukya* rule in the early 7th century. These temples were inspired from the Buddhist architecture as evidenced in Lad Khan temple and Durga temple, at Aihole. The temples evolved from simple rock cut shrines to large and highly complicated structures. The temples in this period were large square building with a projecting porch and decorative pillars. The roof of the temple had small structure which later emerged as the *shikhara*. The rock cut structures developed during the 7th-9th century under the rule of Pallavas. The Pallava rulers lead the way of Dravidian style of temple architecture and they built the temples at Mahabalipuram. During the Pandyas rule the south Indian temples were added with the lofty gateways the *gopurams* at the entrance. The *gopurams* made the temple visually attractive and also provided the temples with an enclosure. The *garbhagriha* (usually square in plan), or the sanctum sanctorum housed the

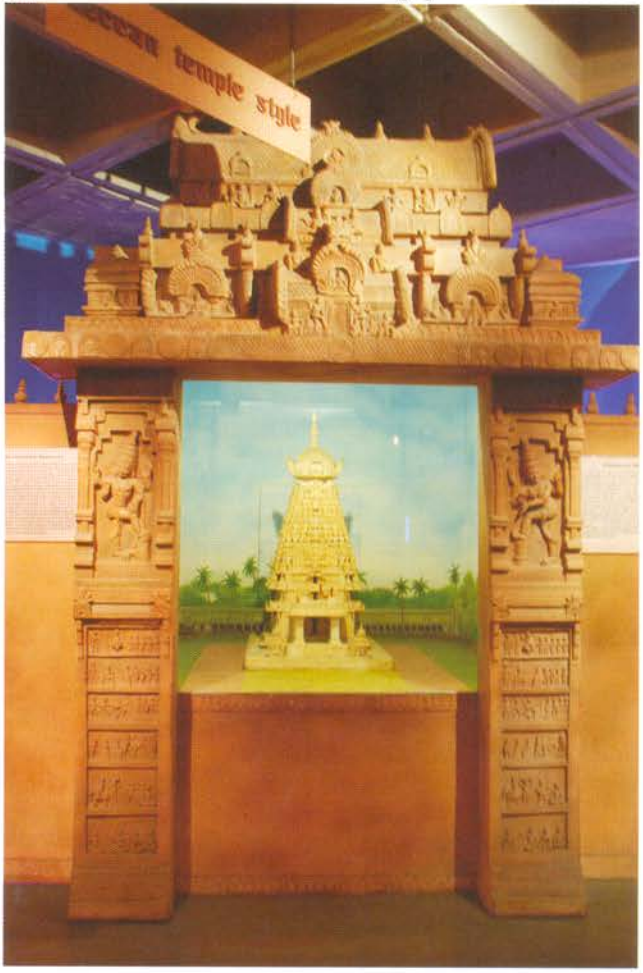

Fig. 5. A model of Brihadiswara temple showing typical temple architecture.

main idols and images of gods and goddesses to which the temple was dedicated and this could be approached through a *mandapa*. The roofs of the temple shrine are pyramidical in shape with a vertically attenuated dome like structure known as the *sikhara*. The main temple as a whole was raised on a massive plinth and was often surrounded by subsidiary shrines and by an enclosing wall with one or more gigantic gateway towers or the *gopurams*[36].

To symbolize this aspect of the Temple architecture in the gallery the next exhibit is created in a specially designed artistic structure that is typical of a south Indian temple architecture. The cabinet houses a scaled down model of one of the tallest temples, with a height of 60 metres, the famous Brihadeshwar temple at Thanjavur (1100 AD) from the Chola dynasty.

Moghul architecture

The beauty of ancient and medieval Indian architecture culminates with the epic saga of the Mughul architecture a glimpse of which is embodied in the great Taj Mahal and other Moghul monuments that include the Red Fort of Agra and Delhi, the forts and monuments in Fathepur Sikri and the Jama Masjid in Delhi. The Taj Mahal complex is one of the most visited and well-known moghul archaeological structures of India that is now one of the seven wonders of the modern world. Numerous publications have covered in detail different aspects of this world heritage complex. The most comprehensive research work on Taj is seen in a book by Koch[37]. The next set of exhibits in the section on architecture are dedicated to the Islamic rulers. The structure of the cabinet is so designed to represent the Islamic style of architecture and housed in these cabinets are the models of the Taj Mahal and the Qutab Minar. Also on display is a model of a typical Masjid with different components that explains the basis of the style of architecture chosen. Visually rich information that supports these exhibits also cover information on several other notable examples of Muslim architecture present in India including the great monuments built under the Adilshahi rulers in the likes of the Gol-Gumbaj, arguably the largest unsupported dome structure in the world, and the Ibrahim Roza monuments at Bijapur. Space being a premium in the gallery and in consideration of the fact that a vast canvas of the subject of our S&T heritage was to be covered in the gallery we had to restrict the section on architecture without covering the great influence and architectures of the Roman style of architecture that India houses which include the famous Victoria Memorial and other famous Churches from Goa that have the Portuguese influence in their architecture styles.

Traditional crafts

The tradition of arts and crafts in India goes well beyond 5,000 years. The exquisite stone and metal sculptures and the lapidary craft of the Harappans are examples of the genius of Indian craftsmen. Even today Indian craftsmen are revered for their unique quality of work. Traditional craft works produced by them are in huge demand both in domestic and international market. Some of the traditional crafts items which have received world acclaim include exquisite textile items like intricately weaved and hand embroidery bedcovers, sheets, cushions, curtains, tablemats, and bags, metal works like bidri and silver filigree, furniture, wooden and marble inlay, finely carved boxes, cabinets, wood furniture, toys, utensils, garden pots, terracotta items, brass and silverware, leather products, papier-mâché products, cane, jute, lac, coir products etc. Most of the units producing utilitarian craft items have now attained the status of small-scale industry. A number of these traditions of crafts have continued to be practiced since ancient and medieval times in India. It is in recognition of this that the gallery has on display exhibits that highlight the traditional crafts of India.

A dedicated exhibit in the gallery show cases some of the exquisite wood works produced by Indian craftsmen including an artistically and richly carved elephant in rose wood. Wood has been an integral part of Indian life and culture since times immemorial. Indian wood craftsmen exhibit the tradition of exquisite wooden handicraft that include impeccable carvings in sandalwood, rose wood, teak wood etc. The vast cultural and ethnic diversity has enabled a variety of motifs, techniques and woodcrafts to flourish in India. Unique in their style, wooden handicraft reflects the mood in Indian heritage. The early wood carved temples bear witness for this. Each

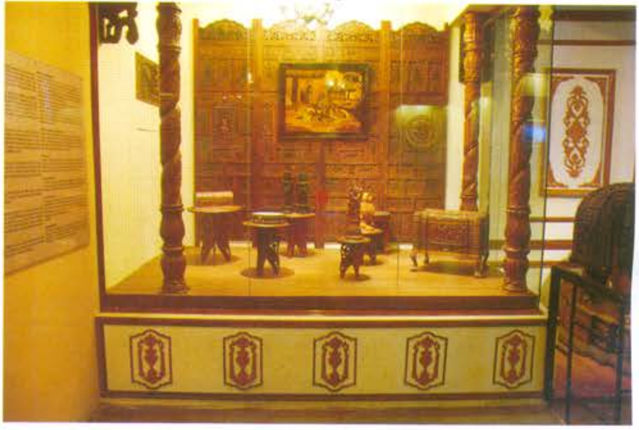
Fig. 9. Collection of exotic wood works.

region in India has developed its own style of wooden structures and carvings. Local traditions and locally available wood varieties influence the style of carvings. Painstakingly carved and inlaid, the wooden articles of Uttar Pradesh are quite a rave with all lovers of woodcarvings. Saharanpur is known for its carvings in hard *sheesham* and particularly for its famous vine-leaf patterns. The range of designs includes floral, geometric and figurative decoration. Uttar Pradesh is also known for its woodwork inlaid with brass wire on ebony or black *sheesham*. The states of Jammu & Kashmir, Gujarat, Karnataka and Kerala also have developed distinctive styles of woodcarvings. Even Rajasthan is noted for its carved sandalwood and rosewood besides heavy ornamental furniture. A variety of wooden works produced by traditional craftsmen exhibiting unique traditional skills have been displayed in the exhibit. These craftsmen who produce these works of art continue to work in the style of their ancestors with the simplest of tools.

Metal crafts

Of all the traditional metal crafts that are being practiced in India the Bidri Ware stands out for its metallurgical excellence. Bidri is valued all over the world for its fine craftsmanship. Its sleek and smooth dark coloured metalwork with intricate eye-catching designs on its glossy surface makes it a unique and highly valued traditional crafts. This metalwork as well as the technique to produce it is found in India since ancient times. Bidri is a high zinc, low copper alloy that contains 76 to 98% (around 95%) zinc, 2 to 10% copper, up to 8%. lead, 1 to 5% tin and trace of iron. The craft of Bidri Ware is a kind of damascene work, which has been defined by Sir Georgy Birdwood as "the art of encrusting one metal on another not in crustae, which are soldered or wedged, but in the form of wire, which by undercutting and hammering, is thoroughly incorporated into the metal which it is intended to ornament./.."[38]. The gallery has on display some exquisite bidri ware products. The exhibition also has on display different stages of making of a bidri ware product which is duly explained in common man's language. A wide variety of exquisite bidri wares from the past are in collection of various museums across India and the ones in possession of the National Museum, Delhi have been duly studied and documented[39]. Bidri wares from India also form a prized collection at the Victoria and Albert Museum, London and these objects too have been thoroughly researched and well documented for their unique metallurgical and artistic properties[40].

Bidri ware involves inlaying of gold or silver on a steel or copper base. The content of zinc in right proportions gives the alloy a typical deep black colour which is so unique to every bidri ware products. It is engraved or overlaid with silver or brass. After casting and moulding, the surface is filed smooth till it acquires the typical Bidri sheen. It is then temporarily blackened with copper sulphate solution and etched into a traditional design using a sharp iron tool. Silver wire or sheets are beaten into the designed grooves, making it stand out like the stars in the night sky. During the final oxidation process, the shiny surface is briefly heated and rubbed with a thick paste of ammonium chloride. The chemical is supposedly mixed with special clay from the walls of the Bidar Fort. It is for this reason that the name Bidri ware is associated with this metal craft. In the final step groundnut or coconut oil is used to polish each item, which may be a vase, bangle, bracelet, goblet, ashtray, plate, Jewellery box etc.

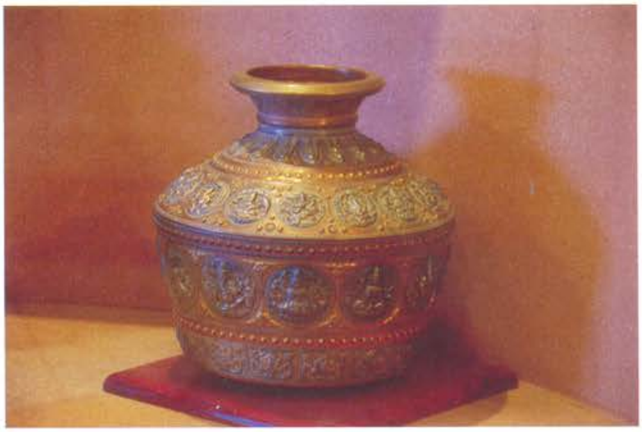

Fig. 10. Intricate Bidri work.

Susan La Niece and Graham Martin have carried out replication experiments and found that the black colour of the *patina* was due to copper. They have also postulated that ammonium chloride preferentially dissolves the zinc from the Bidri Ware and the resulting copper-enriched surface is oxidized by potassium nitrate which produces this black colour[41]. The mystery of the black patina has not yet been fully solved. How the ancient craftsmen developed such intricate chemical procedures are difficult to imagine.

Historical evidence for bidri ware indicates that the beautiful articles presented to Alauddin Bahamani II (1434-57 AD) on the occasion of his coronation impressed him so much that he invited the craftsmen of Bijapur to settle at Bidar itself. The Russian traveller Althanasins Nikitin, who visited Bidar during 1470-74 AD, took with him some of the early Bidri Ware specimens for presentation to the Russian Emperor. A large number of articles of Bidri Ware were made for presentation to the Prince of Wales when he visited India in 1875. Thus the glory and fame of the Bidri ware spread far and wide. Bidar and Hyderabad museums have beautiful collections of this kind of ware. The traditional crafts exhibit also has on display several other products of traditional crafts which are so unique to India.

Musical Instruments

India has a very rich culture in music and the instruments that go with the classical music. The music of India is said to be one of the oldest unbroken musical traditions in the world. The origin of culture of music in India goes back to the Vedic period. C V Raman, Indian Nobel Laureate in Physics, has through his research findings and publications has confirmed that the percussion instruments of India produce pure harmonics in comparison with their western counterparts, which indicates that Indian musical instruments, that support the classical vocal music, were produced with some scientific basis. It is in recognition of this feature that we decided to have a very large exhibit presented in the gallery to portray the rich heritage and culture that India has in the field of music and musical instruments. However to present music in the context of science and technology heritage of India was of great challenge for us. After a brain storming session of the conceivers of the gallery, we decided to present the material evidence that exists to support presence of music and musical instruments in ancient and medieval India in the wonderfully crafted temple sculptures especially in the temples at Belur and Halebidu[42,43]. Karnataka is home to many architecture sites with richly decorated sculptures and some of these sculptures vividly depict the musical instruments. From these musical instruments, found in sculptures, one can apply a traditional Indian classification of musical instruments to note the four categories of the instruments namely: *Ghana vadya* (idiophones); *Avanaddha vadya* (drums, membranophones); *Sushira vadya* (wind instruments, aerophones); *Tata vadya* (stringed instruments, chordphones). These classifications match with the system found in the modern classification method of the musical instruments propounded by Curt Sachs and Erich von Hornbostel.

The exhibit structure symbolically represents typical temple architecture in the Hoysala style with fibre glass fresco sculptures shown on the wall surface. It is supplemented with the display of various types of musical instruments that are found in the Hoysala sculptures seen at Belur and Halebidu. On the wall surface of the exhibit a wired mural display has been created to show case different types of musical instruments that were in vogue in ancient and medieval India. Three large LCD televisions constantly keep scrolling to depict information about various musical instruments that have existed in India since ancient times and how these instruments have been represented in different sculptures. The wire mural line drawings have been created based on the well researched publication of Jean Deloche[43].

Exhibition Information at a glance

One specially designed multimedia based exhibit has been added to the gallery which has visitor interaction facility. Interested visitor can browse through a touch screen multimedia computer screen and chose subject of his choice. He/She will be able to get substantial information on the subject of his choice and this information is spread across three large sized LCD TV screens and each of these TVs show different information which is mostly based on peer reviewed research publications. A typical NCSM interactive technology has been adopted in this exhibit.

Video Wall: The Concluding exhibit

Our Science and Technology Heritage exhibition ends with a video wall, which summarizes, in 12 minutes, very well conceived, scripted, edited and professionally produced video documentary based on researched data, that is exhibited on a very large screen (56 inches each) 2x2 seamless video wall. A visitor who has less time at his disposal to peruse every single written matter of the exhibition has the privilege of comprehending what the gallery is all about by just watching this brief video presentation.

Acknowledgement

I would like to acknowledge the contributions of all the people who were involved in making of "Our Science and Technology Heritage" gallery at Delhi. My thanks are due to the DG, NCSM, Shri G S Rautela and his entire team at NCSM Hqrs., the Chairman, Executive Committee, NSCD, Dr S N Joshi and all EC members of NSCD. Shri Anurag Kumar and Subrato Sen, curators, owe my thanks for playing the key role in conceptualizing and completion of this gallery. The gallery has taken the present artistic shape due to the artistic contributions of Shri Bhargav, Satish Pandita, Banerjee, Sarkar, Bharat and others in art section. Shri Khimnani and his team of workshop technicians have given physical shape to the exhibition. Multimedia and electronics have been artistically blended in the exhibition and were created by Shri Manas Bagchi, Ramdas Iyer, Vijay Shanker, Bharti, Neelu and their team.

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Water - The Elixir of Life : A New Gallery at National Science Centre, New Delhi

N Ramdas Iyer

Abstract

Our Earth is unique because it is the only known place in the universe where water exists as a liquid thus enabling life in all its diversity to thrive here. When the human population was small its effect on the planet and its water bodies was also manageable. But over the past century, it has exploded, thus creating an adverse impact both on quality and quantity of potable water. Human impact has resulted in growth of sprawling cities and towns which pollute our rivers with increasing amounts of waste and threaten our water systems as we squander this precious resource. A new Gallery "Water – The Elixir of Life", conceptualized and opened to the public at the National Science Centre, Delhi is aimed at creating awareness about this scarce and all important source of life among the visitors specially the children.

The exhibits in the Gallery aim to cover the entire gamut of water related issues starting from the science of water, water resources on earth, threat perceptions, conservation methods, importance of water in life and impact of pollution and seemingly innocent cultural practices on our water bodies. It is meant to shock visitors out of their complacency and realize the seriousness of the issue.

Introduction:

Observational records, demographic study and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems. At this juncture, when there are well-researched speculations of ensuing water stress in India, water education, for the students and people, becomes critical. It is in this background that the National Science Centre has conceived and set up a Gallery called "Water - The elixir of life". In this effort the Centre collaborated with the Delhi Jal Board, the principal government sector water supply and sewerage service in Delhi.

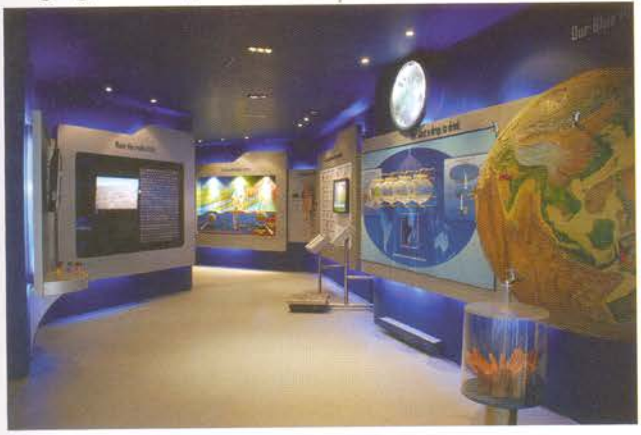

Fig. 1. Water the elixir of life is a gallery in NSC, Delhi that tends to sensitize people on water issues.

In addition to making science accessible, science centres have an added responsibility to educate people on issues relevant to the society and thereby guiding them in taking a stand on such issues. Water issues are one of the most relevant to the continued survival and prosperity of the human race and they need to be portrayed in their entirety so that visitors are made aware of the entire spectrum of the issue.

Water on Earth

As visitors enter the gallery, they become immersed in a watery world. They walk over a virtual surface of a lake, creating ripples. They hear sounds of water trickling, running, crashing, and echoing all around them. Immersive environment created using the Gesturetek Patented Image Processing Technology with white tiling on the floor is employed to create a spectacular introductory theme to the Gallery.

It is an oft repeated statement that the Earth is a blue planet and that more than 70% of the earth is covered by water. While this is mostly true from a layman's point of view, when looked at, seriously, the following figures emerge.

5.1×10^8 Km^2 is the total surface area of Earth and its volume is 1.08321×10^{12} Km^2. Approximately 70.9% of the Earth's surface is covered by water, which means there is 3.61×10^8 Km^2 of water on earth. It has been estimated that 3.79 Kms is the average depth of water on earth. So volume of water on earth works out to 1.36819×10^{10} Km^2. Using the formula of $4\pi r^3$ for the volume of a sphere 1.36819×10^{10} Km^3, we arrive at a diameter of 1377.37 Kms, which is hardly the distance between Delhi and Kolkata. In other words, if all the water on Earth, including those from rivers, lakes, groundwater etc. were to be compressed into a sphere, the sphere will just reach Kolkata from Delhi. This fact is visually and shockingly presented in the introductory exhibit of the gallery[1]. The question we are asking the visitors is "Are we converting the blue planet into a brown planet?"

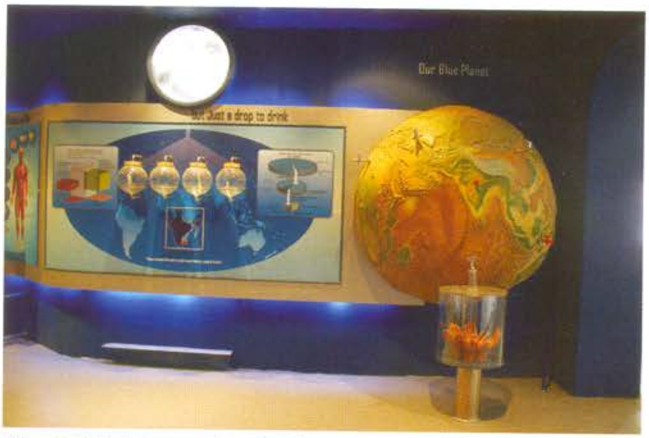

Fig. 2. Exhibit showing the size of a sphere that would contain all of Earth's water in comparison to the size of the Earth. The sphere includes all the water in the oceans, seas, ice caps, lakes and rivers as well as groundwater, atmospheric water, and even the water in us, animals and plants.

Water in our body

Water makes up approximately two-thirds of our body's weight and approximately 75 percent of the brain's weight. Nearly 4 percent of the water in the body is lost through the skin, lungs and through urine and stools each day. This water loss must be replaced continually by water, beverage and food consumption.[2] Water loss resulting in as little as 1 percent decrease in body weight is called dehydration. Dehydration will reduce the body's ability to perform physically and mentally. Infants and children can quickly become dehydrated; therefore, it is critical they consume adequate fluids. Water is so important to well-being that one can only live a few days without it. The Gallery makes use of exhibits which interactively weigh the visitor and gives a detailed reading of the amount of water in her different body organs. This has been a highly popular exhibit and attracts large crowds.

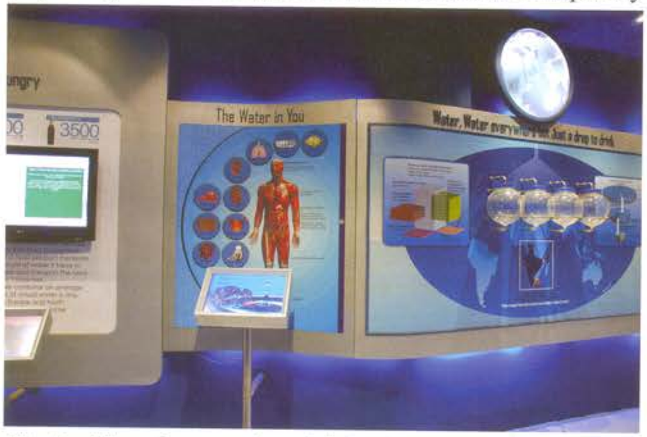

Fig. 3. Water in you - the exhibit which demonstrates that a significant fraction of the human body is water.

Water Properties

Every known form of life on earth, from the largest mammals to the smallest microbes, relies on water. Why? Because water is an extraordinarily versatile molecule - it's the perfect liquid medium in which to dissolve nutrients for ingestion or wastes for excretion and to transport important chemicals. Water has two particular physical properties that are unique among natural molecules: it remains liquid over an extremely broad range of temperatures, and it decreases in density when converted to solid phase (frozen). While this may seem a relatively minor point, its consequences (that ice floats on liquid water) are critical to the evolution of life. If ice were denser than water and the earth cooled slightly, ice formed on the oceans would sink and push the already cold water from the bottom to the surface, where it too would freeze and sink, repeating the cycle until all water on the planet was frozen.

Why does this simple molecule, composed of two hydrogen atoms and one oxygen atom, behave the extraordinary way it does? Many of water's unique properties are largely a result of its chemical structure. The two hydrogen atoms bound to one oxygen atom to form a 'V' shape with the hydrogen atoms at an angle of 105°. When the hydrogen atoms combine with oxygen, they each give away their single electron and form a covalent bond. Excess of electron density on the oxygen atom creates weakly negative regions at the other two corners of an imaginary tetrahedron. This molecular structure makes it the most common, yet, the most unusual liquid. There are several such anomalies in water which make it a crucial component that creates and sustains life. Water is colourless; Water

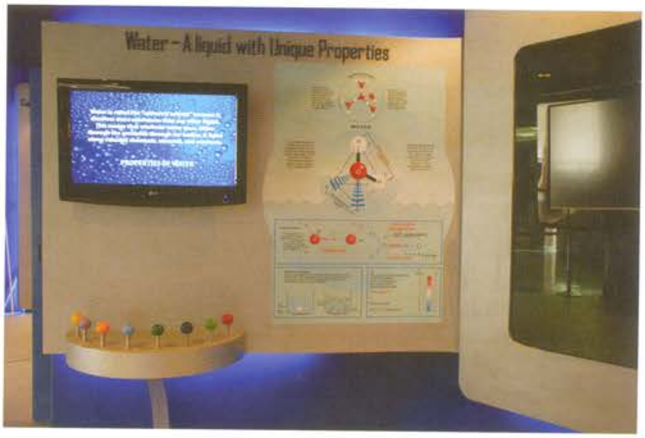

Fig. 4. The simple molecule of water exhibits much uncommon behaviour because of its intra-molecular hydrogen bond. These properties, explained in this exhibit, form the basis of its being the substance of life.

is tasteless; Water is odourless; Water feels wet; Water dissolves a great number of things; Water can absorb a large amount of heat; Water sticks together into beads or drops; Water flows and erodes the surface of the earth; it moves sediments to form lands; It shapes lipid and protein molecules and give them their 3-dimensional form which is critical to their function; It's part of every living organism on the planet.[3] This is demonstrated in an interactive exhibits that showcases some properties of water. It is from water that life on Earth originated. From simple amino acids to single celled organisms to the most sophisticated life forms originated from and depends on water. A film specially procured from Norway shows how water influences the life of humans from life to death.

Water and civilisations

The first great urban developments of the earth were located along rivers that flowed through a virtual desert. Water and waterways sustained those civilizations. The river supplied water; it spread a sheet of alluvial soil that was fertile, the water brought fish with it and later the waterway became an easy means of transport. Major early civilizations like the Mesopotamian or Sumerian civilization, Indus Valley civilization, Egyptian civilization and the ancient Chinese civilization all developed within a thin strip around a river. They were all riparian civilizations. Farming the world over has always relied upon a dependable water supply. For the earliest societies this meant rivers and streams or regular rainfall. The first great civilizations grew up along rivers. Later communities were able to develop by taking advantage of the rainy seasons.

The four places where ancient civilization developed and thrived were riparian. These are Indus Valley in Pakistan and India, Mesopotamian civilization on the banks of rivers Tigris and Euphrates, Egyptian civilization on the banks of the great river Nile and the Chinese civilization on the river banks of Hwangho and Yangtze-kiang. By about 5000 BC, small tribes of farmers in Mesopotamia had made their way to the river valleys. On the floodplains they raised wheat, barley, and peas. They cut through the riverbanks so that water for their crops could flow to lower lying soil. These early irrigation systems were more fully developed by the Sumerians in Mesopotamia, who drained marshes and dug canals, dikes, and ditches. The need for cooperation on these large irrigation projects led to the growth of government and law. Egyptian farmers had settled in the long and narrow valley of the Nile River by 5000 BC. Within 2,000 years they had built massive irrigation works. The primitive farming settlements of Egypt were concerned with the raising of vegetables, grains, and animals. Probably the need to control the Nile floodwaters through dams and canals eventually led to the rise of government in the region.

The valley of the Indus River is considered to be the birthplace of Indian civilization. By 4000 BC primitive farmers were raising vegetables, grains, and animals along the riverbank. By 2700 BC two major cities, Harappa and Mohenjo-Daro, and numerous smaller towns had emerged. They had great public water baths and granaries. These cities had the finest sewage and wastewater systems of the ancient world. These cities even had underground cesspools that were implemented in modern cities of the world only after 1600 AD.[4,5,6]

Societal impacts of water scarcity

Global Freshwater reserves are rapidly depleting and this is expected to significantly impact many densely populated areas of the world. Low to middle income developing regions as well as highly developed countries will face water stress in the future, unless existing water reserves are managed effectively. Although low and middle income developing countries currently have low per capita water consumption, rapid growth in population and inefficient use of water across sectors is expected to lead to a water shortage in the future. By 2025, India, China and select countries in Europe and Africa will face water scarcity if adequate and sustainable water management initiatives are not implemented.[7] By 2025, an estimated 3 billion people will be living below the water stress threshold. Between 1995–2025,

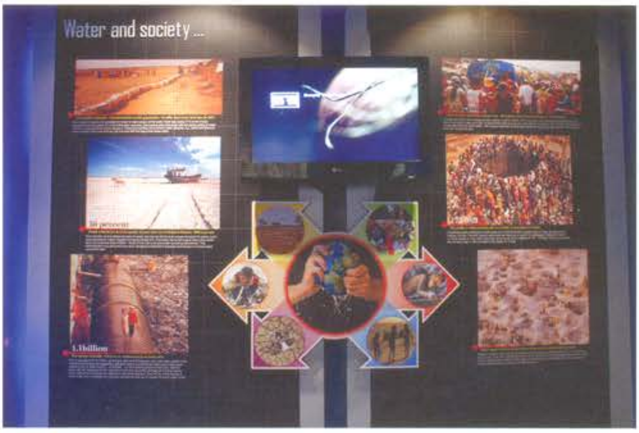

Fig. 5. Imbalances between availability and demand, the degradation of groundwater and surface water quality and intersectoral competition all contribute in water scarcity and its effects are manifest in many societal discomforts. The idea explained in graphics and video.

global population and per capita water consumption are projected to grow at a CAGR (Compound Annual Growth Rate) of 1.16% and 0.67% respectively. Densely populated and developing regions of the world, such as Asia and Africa are expected to face the maximum water stress. There are several exhibits in the Gallery which talk about the ensuing water stress and how we as citizens can do our best in staving it off.

Severe water shortages have already led to a growing number of conflicts across the country. Some 90 percent of India's territory is drained by inter-state rivers. The lack of clear allocation rules, and uncertainty about what water each state has a right to, imposes high economic and environmental costs. There are great variations in current per-capita water availability for each continent. Oceania has over 70,000 cubic meters per person per year (m3/person/year), the average for all of Africa is under 7,000 m3/person/year, while that of Asia is only 3,400 m3/person/year. Even greater disparities are noticeable if one looks at a national or regional basis.[8]

The urban scenario – Delhi: A case study

Delhi is currently the fastest growing metropolis in India. Among the six Indian mega-cities with a population over 5 million people, Delhi is the only one whose population grew at an annual growth rate greater than 4% during the last decade as compared to 2.62% in Mumbai, 1.82% in Kolkata and 3.2% in Bangalore. According to the Census 2001, the population of the national capital territory of Delhi was 13.85 million people, to which can be added the more than 3 million people living in the extensions of the Delhi's urban agglomeration outside the NCT. In 2021, projections of population for the NCT are between 22 and 23 million, and around 10 million inhabitants in the different adjacent cities, making it the second largest urban agglomeration after Tokyo.[11]

Delhi receives most of its water supply from the Yamuna and the remaining from groundwater, the Ganga Canal, the western Yamuna canal, and the Bhakra. Average water consumption in Delhi is estimated at being 240 liters per capita per day (lpcd), the highest in the country. Who brings it to your tap? Through elaborate planning and installation, the Delhi Jal Board has ensured average availability of 50 gallons filtered water per capita per day for the residents of Delhi, through a network of about 9000 kms of water mains/lines. Delhi is experiencing increasing pressure to meet demand for its water resources. Growing urbanization, improvements in living standards, exploding population are just some of the contributing factors. Average water consumption in Delhi is estimated at being 240 liters per capita per day, the highest in the country. Water treatment plants (WTP) and sewage treatment plants (STP) in Delhi ensure that the best possible is done to ensure adequate per capita availability of water to each citizen, but unless the citizens cooperate it is a losing battle. Interactive working models of WTPs and STPs explain how these work in ensuring a clean supply of water.

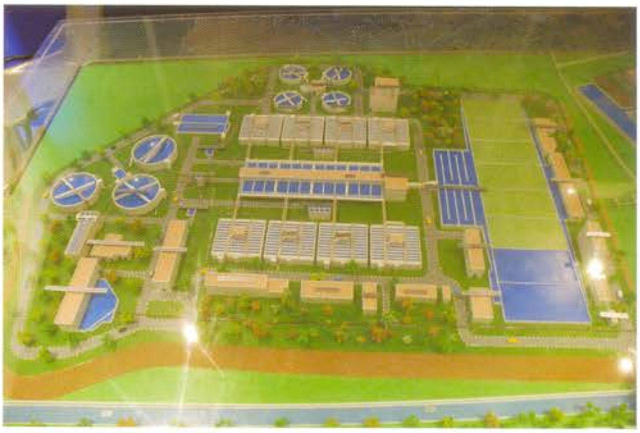
Fig. 6. Model of the Sonia Vihar water treatment plant that processes and supplies 140 million gallons of potable water per day.

Delhi has an adequate supply of water. With over 200 litres of water available per capita per day it has more water than many other big cities in the world that provide their residents with 24X7 water supply. Altogether, 80% of the 16 million people living in the National Capital Territory of Delhi (NCTD) has access to piped water and 75% to sewers. But about 15% of the population has no access to sanitation facilities. India faces a turbulent water future. Unless water management practices are changed – and changed soon – India will face a severe water crisis within the next two decades and will have neither the cash to build new infrastructure nor the water needed by its growing economy and rising population. Today, 70 percent of India's irrigation needs and 80 percent of its domestic water supplies come from groundwater. Although this ubiquitous practice has been remarkably successful in helping people to cope in the past, it has led to rapidly declining water tables and critically depleted aquifers, and is no longer sustainable.

Water usage and water footprint

The water footprint of a country is defined as the volume of water needed for the production of the goods and services consumed by the inhabitants of the country. People use lots of water for drinking, cooking and washing, but even more for producing things such

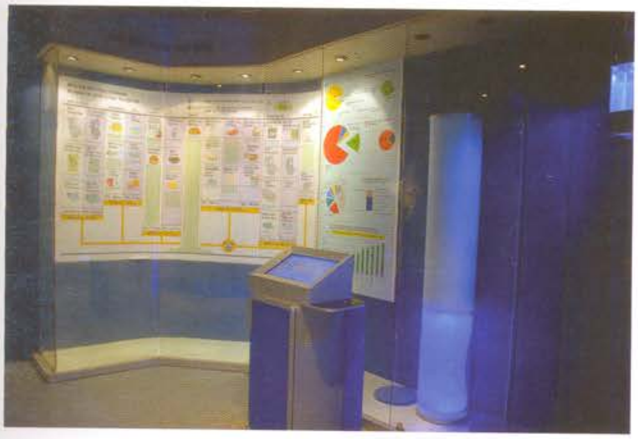

Fig. 7. An interactive exhibit for calculatng an individual's water footprint from his household data and water usage pattern.

as food, paper, cotton clothes, etc. The water footprint is an indicator of water use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.[9] The exhibit on water footprint of the visitor is made interactive using an electronic-computer-mechanical-pneumatic interface, developed for the first time and depending upon the choices made by the visitor using a computer screen, shows her the amount of water she uses in a day as a rising water column. This also has created a lot of interest.

A very interesting exhibit asks the visitor whether we are thirsty because we are hungry. Very few people realize that the 4-5 litres of water that they drink daily or even the 100-150 litres that they use for personal hygiene constitutes the total water consumption by them. This is contrary to the fact. Every product that we use is produced using water. There is an interactive exhibit which talks about which product consume how much water to produce. A kilogram of beef needs over 15,000 litres of water. Non vegetarian food is especially costly in terms of water. Even wheat and rice need upto 1500 litres of water per kilogram for production. Considered this way our indirect water consumption is huge.[10] This exhibit has the very desirable trait of shocking people, and the curator has had many curious visitors asking him if the facts depicted in the exhibit is indeed true, and explanation of the details leaves the visitor wondering. In the press coverages following the inauguration, this was one aspect that was widely reported and discussed. The dignitaries in the inauguration also expressed wonder at this unknown fact.

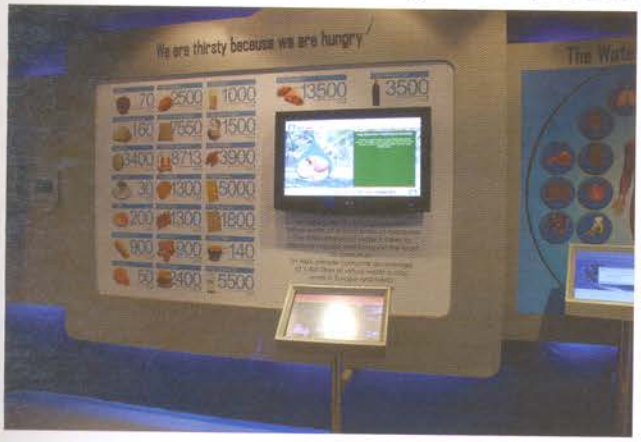

Fig. 8. We are thirsty because we are hungry – an exhibit that makes one to think that food production requires a lot of water and that increases our water footprint a lot.

Threats and opportunities

Bottled water is a recent menace. While Municipal water suppliers supply water of comparable quality at a cheap price (for example, the cost of one litre of water at the tap at our homes as provided by Delhi Jal Board is 17 paise, the same quantity costs Rs.12/- when bought in a bottle. This also comes with the added complication of production and disposal of plastic waste. The energy consumed in production and disposal of bottles in India alone can be used to run 1,00,000 medium sized cars for 365 days. These shocking facts are presented in an attractive graphic. The amount of waste generated on account of the bottled water menace is shown by displaying the amount of bottles used and discarded at the National Science centre in one day.

Water conservation methods, rainwater harvesting, and water efficiency at homes are represented in different exhibits in the Gallery. Simple steps like using a low head shower, cleaning cars using wet rags rather than with a hose pipe, fixing leaking taps etc, can save a lot of water at home. A WTP uses up a lot of money and energy to purify water, but nature does it free of cost in the form of the water cycle. The water cycle is the cycle water goes through on Earth. It makes the rain, clouds, and most of our weather. First, water on the earth is evaporated by the heat from the Sun. Then, water collects as water vapor in the sky. This makes clouds. Next, the water in the clouds gets cold. This makes it liquid again. When it rains, the water then collects into lakes, oceans, or aquifers. From there, it evaporates again and continues the cycle. This is shown as an electromechanical animation. To emphasise the fact that the content of water on earth has remained the same since it was formed, a graphic telling the visitors that the water we drink today is the same water that the dinosaurs drank millions of years ago is highlighted.

Conclusion

In conformity with the principle of taking a stand on issues, the Gallery raises a question of whether our cultural and religious practices are degrading rivers. While it is a sensitive issue, we cite quotations from scriptures of all major religions which exhort respect to water and water bodies alongside and ask the visitor to refrain from choking rivers with our cultural practices.

Some other interesting formats of presentation involve an interactive virtual book, where the visitor flips pages of a virtual book on a 42" screen by waving his hands to learn about different aspects of water conservation. This virtual book contains text, videos and pictures. Another is a quad display with a touchscreen interface where the visitor can ask different doctors about different water borne diseases and get live video answers in Hindi or English from them while showing methods of cure, prevention, causes and symptoms of each. Both these exhibits have been well appreciated.

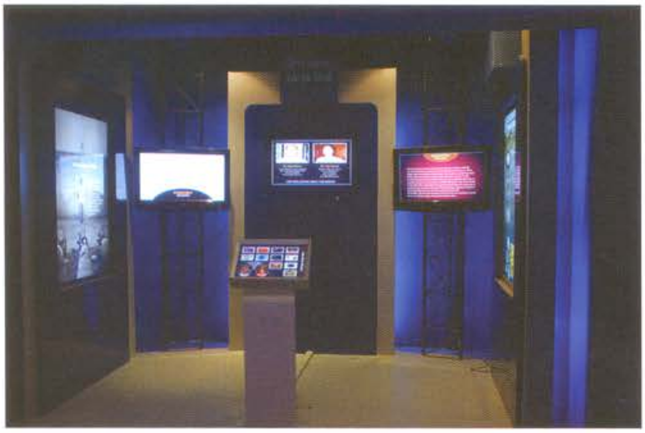

Fig. 9. The exhibit where one may ask a doctor about a particular water-borne disease.

And towards the end there is an unmanned quiz on water issues. The last exhibit is a pledge. The visitor registers a pledge to treat the Yamuna with respect and help prevent its degradation and affirms his pledge with his thumbprint which is recognized and stored along with other relevant details. The next time the visitor uses this exhibit, he is immediately recognized and is asked whether he has kept his pledge. The Honourable Chief Minister of Delhi, who inaugurated the Gallery, was the first to pledge her commitment to the Yamuna.

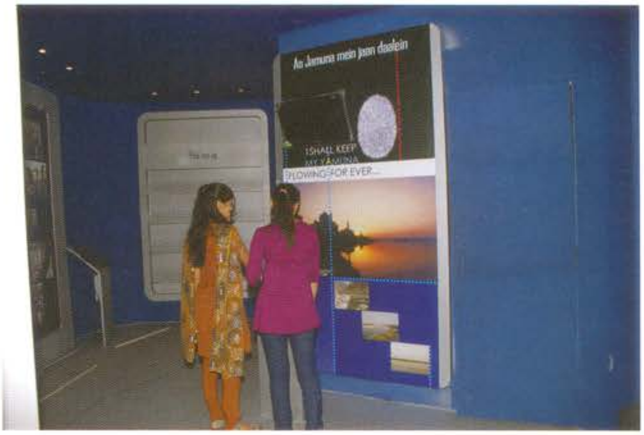
Ab Jamuna mein jaan daalein
I SHALL KEEP MY YAMUNA FLOWING FOR EVER...

Fig. 10. People taking digital pledge to keep the Jamuna clean.

The Gallery since its inauguration has seen a huge influx of visitors who come specially to see this Gallery. In fact, people at the NSC, Delhi ticket counters these days often ask for tickets of this gallery only. The appreciation received has been tremendous. Completed in a record time of six moths since it was first mooted, it is also a testimony to the principle of partnering with stakeholders in social issues (in this case, the Delhi Jal Board), to achieve a common objective, thereby saving costs, enhancing quality and at the same time taking to the hundreds of thousand of visitors the social message that the sponsoring agency has a stake in.

Acknowledgement

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Social Inclusion through Science Centre Activities in India

Arijit Dutta Choudhury

Since independence India has had an established policy and willingness to recognise and address different forms of social inequality and exclusion and has time to time used constitutional and legislative mechanisms to address them. In spite of established policies and efforts at different governmental levels and non-governmental forums, there continues to be large disparity between regions and social groups as well as physical, mental and gender inequalities. Empowering the socially excluded population in all spheres of activities is therefore essential for the overall development of the country.

In the context of non-formal education, science literacy is also as important as other forms of literacy. It is also a powerful tool for social inclusion. Science centres have relevance to all sections of the population and have become an important interface between science and society. Since these centres operate across geographical, economic, political, religious and cultural boundaries they impact the well-being, education, and skills of current and future generations. In this brief, an attempt has been made to examine the activities of science centres and museums aimed at bringing about social inclusion through special programmes, and especially by the National Council of Science Museums (NCSM) to bring in new facets of science and technology to fulfil the Council's mandate of popularising science and technology.

Some of the factors responsible for social exclusion in the context of visits to science centres and museums are the following:

☐ Geographical remoteness of residence with respect to the nearest science centre/museum
☐ Lack of education and associated enigma
☐ Physical, visual, hearing, speech and locomotor disabilities
☐ Stratification due to age, occupation and educational background, since most science centres and museums adopt "one size fits all" approach
☐ Economic constraints of an individual or family group.

For India to be globally competitive in the 21st century, a critical factor would be the ability to harness the knowledge potential of its people. With 550 million people below the age of 25, human capital is India's greatest asset. To best utilise this bourgeoning potential the country needs a knowledge oriented paradigm and focussed capacity and quality building in the field of education. In this context great emphasis needs to be focussed towards rural India, which has a large population base and a potential that can be realised only with a knowledge uplift of the rural populace. Realising the potential and importance of special programmes for the rural masses, NCSM had introduced mobile science exhibition buses nicknamed "museobuses" operating from Birla Industrial and Technological Museum, Kolkata. Over the years, these mobile exhibitions have spread all over the length and breadth of the country through a network of 26 science centres. This special programme for the less privileged rural masses with limited access to urban facilities has been in operation for over four decades. Continuous upgrade of this programme is expected to go a long way in empowering the excluded population with new knowledge that would ultimately contribute to nation building.

A recent addition to activities of NCSM with a similar objective is the collaboration with the local education authorities to bring rural underprivileged children to major science centres under the central government's *Sarva Shiksha Abhiyan*. Special package programmes have been devised by several science centres under the Council as an incentive to encourage visit. Through this scheme the state education departments have been sponsoring the visit of students to the nearest science centres. The process, which started a year back, has yielded very encouraging response and it is very heartening to see some state authorities even arranging local stay for one or two nights for students from far flung rural areas. The visits are made more fruitful by including visits to a number of educational institutions during one such trip.

In a similar vein, special interventions are necessary to ensure greater access to both formal and non-formal education of educationally deprived categories in urban conglomerations. A large section of urban children are deprived of primary education through formal systems due to financial constraints and pressure to earn livelihood for their dependent family members. These children, if not attended to with proper care during their formative years, are likely to become a burden to the society and therefore need special attention. While NGOs and voluntary organisations, with both governmental and philanthropic support, extend free education and other welfare measures, science centres can play an important role as facilitators in this mission. NCSM in the recent past have initiated special programmes for these underprivileged urban children and strengthened these activities with focus on issues of current relevance that would be of mutual benefit for the science centres in fulfilling their mandate and also the society in growing with a more knowledgeable population. As a step in this direction, science centres under the Council have initiated special programmes for the economically underprivileged children of the city and adjoining areas in association with NGOs and other voluntary organisations. Guided visits to exhibitions, immersive experience, and special extension activities are being organised on a regular basis and a large number of disadvantaged children are now privileged to visit the science centres.

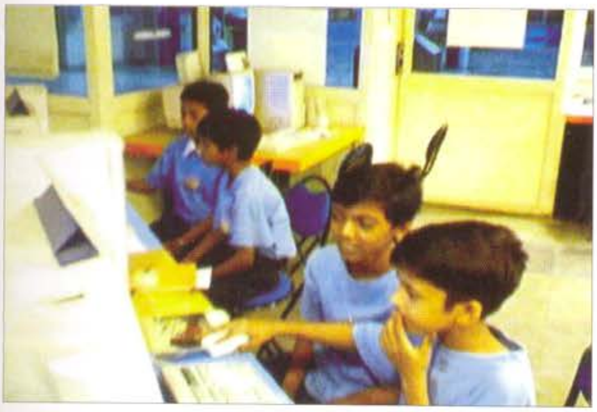

Fig. 1. Computer training programme for street children at Nehru Science Centre, Mumbai.

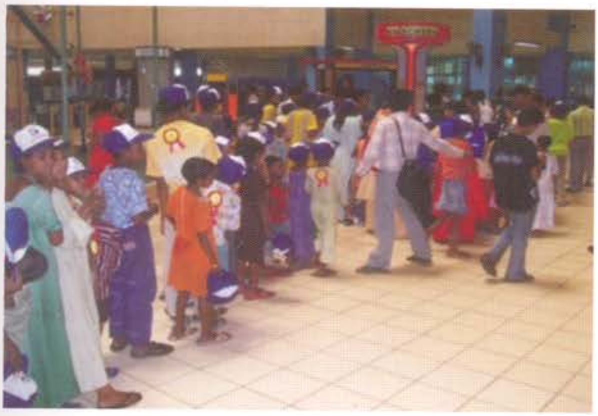

Fig. 2. Under privileged children at Science City with support from local voluntary organizations.

Similarly, the needs of the physically disadvantaged have to be factored in more thoroughly within the ambit of science centre activities. Being public places, the goal of all science centres and museums should be inclusive, which means that all infrastructures and facilities must be oriented to allow the greatest possible access to people with different needs and abilities. While most science centre buildings under the Council have provisions for access and navigation for the visually impaired and the physically handicapped for majority of its facilities and instructive method implementation, a key factor for inclusiveness needs more attention from both exhibit designers and front end educators at the expositions. In a similar vein, educators have to be sensitised and empowered to deal with people with different abilities. Major steps in this direction have been the pioneering efforts of Regional Science Centre, Guwahati of putting up Braille labels at exhibits at the aromatic and medicinal plant corner and a novel exhibition titled "The World of Darkness" for the visually impaired at the Birla Industrial & Technological Museum, Kolkata. Both these facilities have received encouraging response from the users and shall motivate exhibit designers to consider this aspect in future projects as well as in existing installations wherever feasible.

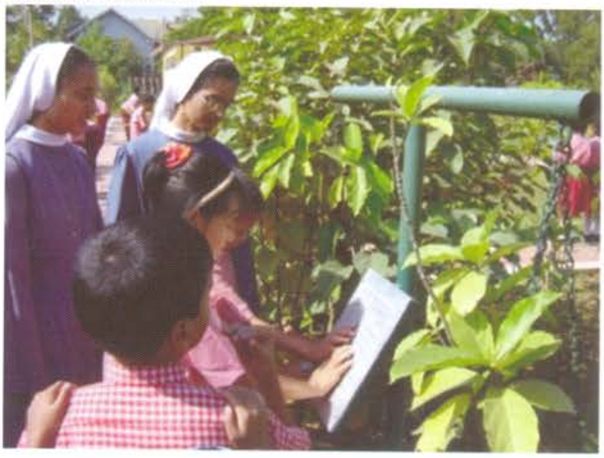

Fig. 3. Blind students at Medical & Aromatic Plant Corner at Regional Science Centre, Guwahati.

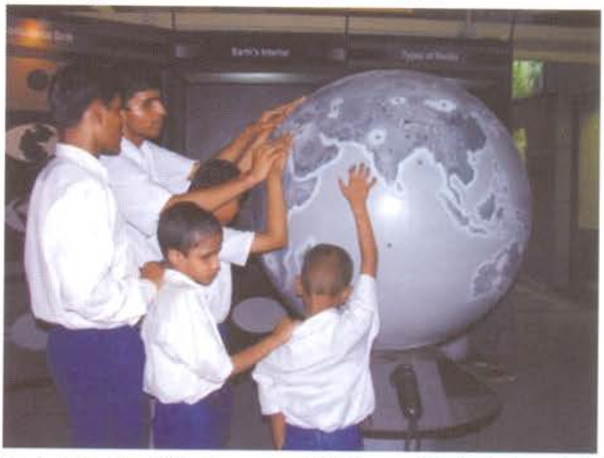

Fig. 4. World of Darkness exhibition at Birla Industrial & Technological Museum, Kolkata.

Special short-duration programmes have been in practice at most science centres and more such attempts of permanent displays are the ultimate goal for inclusive growth. In this regard partnerships with special institutions catering to differently abled population that provide sustained and sympathetic support for learners with special needs and the severely disabled shall benefit both the science centres as well as end users.

Vocational training is an important element in building a knowledge society. Specialised training programmes for people of different educational attainments need to be devised for both rural and urban populace in order to be effective in the changing national context, and for India to enjoy the fruits of trained manpower. In the context of inclusive growth, it is crucial to develop new skills and technological literacy in order to promote employability among people with low incomes. Unless this is done, social exclusion processes would be further aggravated. It is equally necessary to recognise local requirements in competencies, to improve lifelong learning for all. The Council through its network of science centres has over the past two decades extended vocational training primarily at its District Science Centres for the community at large. Such programmes have not only benefitted the trainees in earning their livelihood but have also catered to the Government's inclusive policy to impart vocational training for people of different educational attainments. These programmes have been arranged through consultations with local industry groups and the advisory committees and are part of regular activity schedules of most district science centres. Efforts for appropriate accreditation and certification of the training programmes by appropriate authorities would further benefit the trainees, giving them an opportunity for absorption by the industry.

Stratification due to age, occupation, and educational background has been an important issue for social exclusion, especially in today's realm of new knowledge and changing technology. Science centres and museums are platforms where skills of current and future generations, cutting across geographical and social boundaries, can be suitably addressed for inclusive growth of all segments of society. In this context, with the advent of information technology and its associated benefits, National Council of Science Museums in collaboration with Intel established in 1996 two state-of-the-art multimedia labs called 'Intel Cyberskools' in National Science Centre, Delhi and Nehru Science Centre, Mumbai.

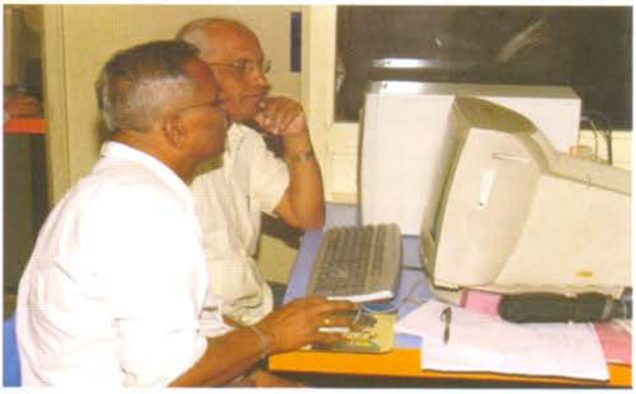

Fig. 5. Computer Awareness Programme at Nehru Science Centre, Mumbai.

The labs initially gave school children and teachers easy access to Pentium-processor based multimedia computers, educational software and the Internet, which at that time had very limited penetration in homes across the country. The facility was very soon extended to senior citizens and homemakers and became a very successful activity at both these Cyberskools, reflecting the hunger for new knowledge, which had remained out of bounds due to their age, occupation and other social factors. While interacting with senior citizens and homemakers, the focus was to dispel the perceived fear from their minds from the initial stage of contact and to project a welcoming atmosphere. The interest of this segment was sustained by ensuring that the training was appropriately paced and was presented in an easily understood format void of jargons normally associated with the subject.

To conclude, professionals working in science centres and museums have to continuously evolve strategies, considering primarily local requirements to make their institutions more socially inclusive, widen access to their exhibitions and activities, and build in a manner that is conducive to pursue social inclusion as an important aspect in all developmental and educational activities.

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The Metrology behind Harappan Town-Planning

Michel Danino

Abstract

The existence and use of Harappan linear units have remained a riddle. Harappan town planning, in particular, has not so far been known to have used precise units, although it displays elaborate geometry. This article proposes that the site of Dholavira, in the Rann of Kachchh, enables us to calculate a possible linear unit used to lay out the fortifications. This unit, which works out to 1.9 m, is then related to a proposed Harappan angula of 1.76 cm, with a factor of 108 between the two, as indicated in later classical literature.

Besides other Harappan sites, independent research at early historical and historical sites and structures — e.g., Taxila, Shishupalgarh, Thimi and the Delhi Iron Pillar — is quoted as confirmation of the proposed system — an important case of continuity between India's two urbanizations.

Dholavira's Plan and Proportions

Dholavira (23°53'10" N, 70°13' E) is probably the most spectacular Harappan site to be seen after Mohenjo-daro, and, at 48 hectares, the second largest in India (after Rakhigarhi in Haryana). Discovered by the late Jagat Pati Joshi in the 1960s on the Khadir island of the Rann of Kachchh, it was excavated in the 1990s under the direction of R.S. Bisht of the Archaeological Survey of India. The Harappans' motivations in setting up this large city in such a harsh and forbidding environment must have been intimately related to access to raw materials, craft production and trade. There is evidence that the Rann of Kachchh was navigable in Harappan times, which would have given Dholavira access to the sea.[1] As a regional capital, Dholavira must have exerted a measure of control over the hundreds of smaller Harappan sites dotting Kachchh, Saurashtra and mainland Gujarat. It flourished during the Mature Harappan phase, that is, between 2600 and 1900 BCE.

Even if the climate might have been slightly more congenial than it is today, the establishment of such a city in this location is a feat of planning, engineering, labour control and execution, especially in the field of water harvesting and management: Dholavira's colossal water structures, covering some 17 hectares and often interconnected through underground drains, were the *sine qua non* of the city's survival through the year.

Like most Harappan sites, Dholavira followed a strict plan, but one of its kind with multiple enclosures. While Harappan town-planning is often based on an acropolis / lower town duality (as at Mohenjo-daro and Kalibangan), Dholavira's plan (Fig. 1) is triple: an acropolis or upper town consisting of a massive "castle" located on the city's high point and an adjacent "bailey"; a middle town, separated from the acropolis by a huge ceremonial ground; and a lower town, part of which was occupied by a series of reservoirs. (Terms such as "castle", "bailey", etc., are those of the excavator.)

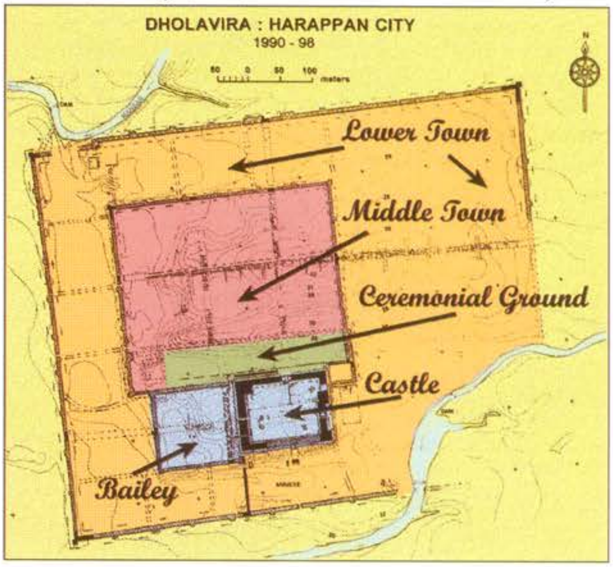

Fig. 1. Plan of Dholavira (adapted from Bisht 1999).

A mere look at the plan suggests a complex conceptual background. Can we make some sense of the concepts and rules Dholavira's urban architects followed? To do so, we need to study the dimensions of the various fortifications, which were precisely measured by the ASI team. Table 1 summarizes them,[2] with a maximum margin of error of 0.5%.[3] Importantly, the three longest dimensions have since been confirmed by GPS readings.[4]

Dimension	Measurement (in metres)	
	Length	Width
Entire city	771.1	616.85
Middle town	340.5	290.45
Ceremonial ground	283	47.5
"Castle" (inner)	114	92
"Castle" (outer)	151	118
"Bailey"	120	120

Table 1: Dholavira's dimensions

It became immediately clear to the excavator that these dimensions obeyed precise ratios or proportions. Bisht highlighted some of them as follows (I have added in parentheses the margins of error calculated on the basis of Table 1 and rounded off to the first decimal):

1. The city's length (east-west axis) and width (north-south) are in a ratio of 5:4 or 1.25 (0.0%, a perfect match).
2. The "castle" also reflects the city's ratio of 5:4 (0.9% inner, 2.4% outer).
3. The "bailey" is square (ratio 1:1).
4. The middle town's length and breadth are in a ratio of 7:6 (0.5%).
5. The ceremonial ground's proportions are 6:1 (0.7%).

All but one ratios are verified within 1%, an excellent agreement considering the irregularities of the terrain. In two papers,[5] I worked out a few other important ratios at work in Dholavira, some of which would have been chosen by the town-planners in order to define the whole city geometrically, others following as consequences of those initial choices. The principal ratios are summarized in Table 2 and Fig. 2. Not only are the margins of error very small, but the repetition of ratios 5:4 and 9:4 cannot be accidental.

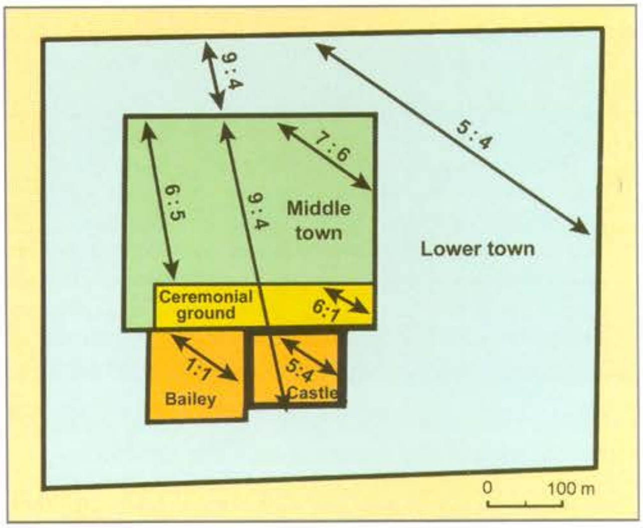

Fig. 2. Main ratios at work in Dholavira's plan

Dimension	Ratio	Margin of error(%)
Entire city*	5:4	0.0
"Castle", inner*	5:4	0.9
"Castle", outer*	5:4	2.4
"Bailey"*	1:1	0.0
Middle town*	7:6	0.5
Ceremonial ground*	6:1	0.7
Castle's outer to inner lengths**	4:3	0.7
Middle town's length to castle's internal length**	3:1	0.4
Middle town's length to castle's outer length**	9:4	0.2
City's length to middle town's length**	9:4	0.6
Middle town's length to ceremonial ground's length**	6:5	0.3
* = proposed by R. S. Bisht ** = proposed by Michel Danino		

Table 2. Dholavira's ratios and margins of errors

Dholavira's Master Unit of Length

How were Dholavira's town planners able to impose such a set of precise ratios and dimensions on the ground? Two assumptions appear reasonable at this stage: (1) they must have used a standard of length; (2) they chose integral (or whole) multiples of this standard for as many of the main dimensions as possible. I propose that there is a simple way to calculate the main linear unit used at Dholavira.

Let us call it "D" for Dholavira. Elsewhere,[6] I used a simple procedure to calculate the largest possible value of D that will result in most of the city's dimensions being expressed as integral multiples of D. The procedure, briefly put, consists in algebraically expressing the smallest dimension in our scheme (i.e., the average width of the castle's western and eastern fortifications) as a multiple of the unknown unit D (or nD, n being an integer); then, using all available ratios, to express all larger dimensions in terms of nD. We find, of course, that a few dimensions are not integral but fractional expressions of nD. To make those fractions disappear, we choose "n" as the least common multiple of their denominators. It turns out that with n = 10, all fractional results disappear, except one. Going back to our initial formula, the width of the castle's western and eastern fortifications, which we expressed as nD, is now 10 D. Bringing into play the proportions listed above, we can express all but one dimensions as multiples of D. Fig. 3 summarizes the findings.*

We now only need to determine the value of D, which is simply derived from the city's length: if 771.1 m = 405 D, then D = 1.904 m or 190.4 cm, which we may round off to 1.9 m.

Starting from this value and calculating the theoretical dimensions backward using Fig. 3, we can compare them with the actual dimensions. Table 3 lists the results, as well as the margins of error between theoretical and actual dimensions. The latter are remarkably modest, 0.6% on average (the highest being, again, in the outer dimensions of the "castle"). These almost perfect matches appear to rule out the play of chance.

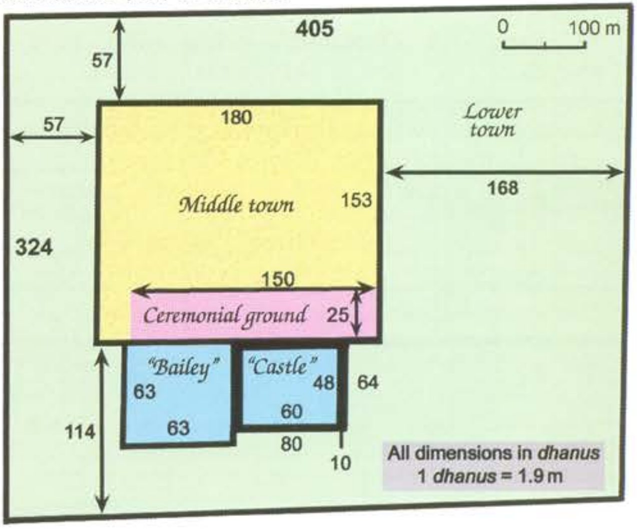

Fig. 3: Dholavira's main dimensions expressed in terms of dhanus, Dholavira's master unit of length.

Dimension	Length (in terms of unit D)	Theoretical measurement (in metres)	Actual measurement (in metres)	Margin of error (%)
Lower town's length	405	771.1	771.1	0.0
Lower town's width	324	616.9	616.85	0.0
Middle town's length	180	342.7	340.5	+0.6
Middle town's width	154.3	293.8	290.45	+1.1
Ceremonial ground's length	150	285.6	283	+0.9
Ceremonial ground's width	25	47.6	47.5	+0.2
Inner castle's length	60	114.2	114	+0.2
Inner castle's width	48	91.4	92	-0.7
Outer castle's length	80	152.3	151	+0.9
Outer castle's width	64	121.9	118	+3.2
Bailey's length & width	63	120.0	120	0.0

Table 3: Comparison between theoretical and actual dimensions.

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* The exception is the middle town's width, but this is normal. If the middle town's length is, as produced by these calculations, 180 D, with a ratio of 7 : 6 between them, the width cannot be an integral multiple of D; it will be about 154.3 D. (In reality, at 290.45 m, it is almost 153 D).

Ratios in Harappan Settlements

For whatever reasons, Harappans clearly preferred certain fixed ratios to random proportions. This is visible not just at Dholavira but at other Mature Harappan sites, as the following selective list shows (in increasing order):

* Ratio 7:6, the ratio of Dholavira's middle town, is found in the dimensions of the "assembly hall", also called "pillared hall", on the southern part of Mohenjo-daro's acropolis, which measures "approximately 23 by 27 metres".[7]

* Ratio 5:4, Dholavira's prime ratio, is found elsewhere in Gujarat at Lothal, whose overall dimensions are 280 x 225 m,[8] and Juni Kuran (just forty kilometres away from Dholavira in Kachchh), whose acropolis measures 92 x 72 m,[9] which approximates 5:4 by 2.2%. It is also reflected in Harappa's "granary"[10] of 51.2 x 40.8 m (with a precision of 0.3%) and in a major building of Mohenjo-daro's HR area[11] measuring 18.9 x 15.2 m (0.5%). Ratio 5:4 is repeated in other ways. At Dholavira, for instance, there are 5 salients on the northern side of the middle town's fortification, against 4 on its eastern and western sides (if we include the corner salients, their numbers grow to 7 and 6, which reflect the middle town's ratio). Returning to Mohenjo-daro's "pillared hall", it had four rows of five pillars each.[12] It is quite intriguing that this hall, in its dimensions (7:6) as well as rows of pillars (5:4), should reflect Dholavira's two key ratios!

* Ratio 4:3 is visible in Mohenjo-daro's "granary" (also called "warehouse"): this structure is composed of 27 brick platforms (in 3 rows of 9); while all platforms are 4.5 m wide (in an east-west direction), their length (in a north-west direction) is 8 m for the first row, 4.5 m for the central row, and 6 m for the third row.[13] It is singular that both pairs (8, 6) and (6, 4.5) precisely reflect the ratio 4 : 3.

* Ratio 3:2 is the overall ratio of Kalibangan's lower town (approximate dimensions 360 x 240 m),[14] as well as of a sacrificial pit (1.50 x 1 m).[15] It is also the ratio of three reservoirs at Dholavira: one in the "castle" measuring 4.35 x 2.95 m,[16] and two larger ones to the south of the castle.[17] We find it again (within 1%) at Mohenjo-daro in the overall platform of the "granary", which measures 50 x 33 m.[18]

* Ratio 2:1 is that of Dholavira's acropolis ("castle" and "bailey" together); it is also found at Mohenjo-daro[19] (whose acropolis rests on a huge brick platform measuring 400 x 200 m), Kalibangan[20] (acropolis of 120 x 240 m) and Surkotada[21] (overall dimensions 130 x 65 m).

* Ratio 9:4, apart from its double presence at Dholavira, is found at Mohenjo-daro's long building located just north of the Great Bath, called "block 6" and measuring approximately 56.4 x 25 m,[22] thus within 0.3%.

* Ratio 7:3 is found at Harappa's mound AB in "14 symmetrically arranged small houses",[23] each measuring 17.06 x 7.31 m (nil margin).

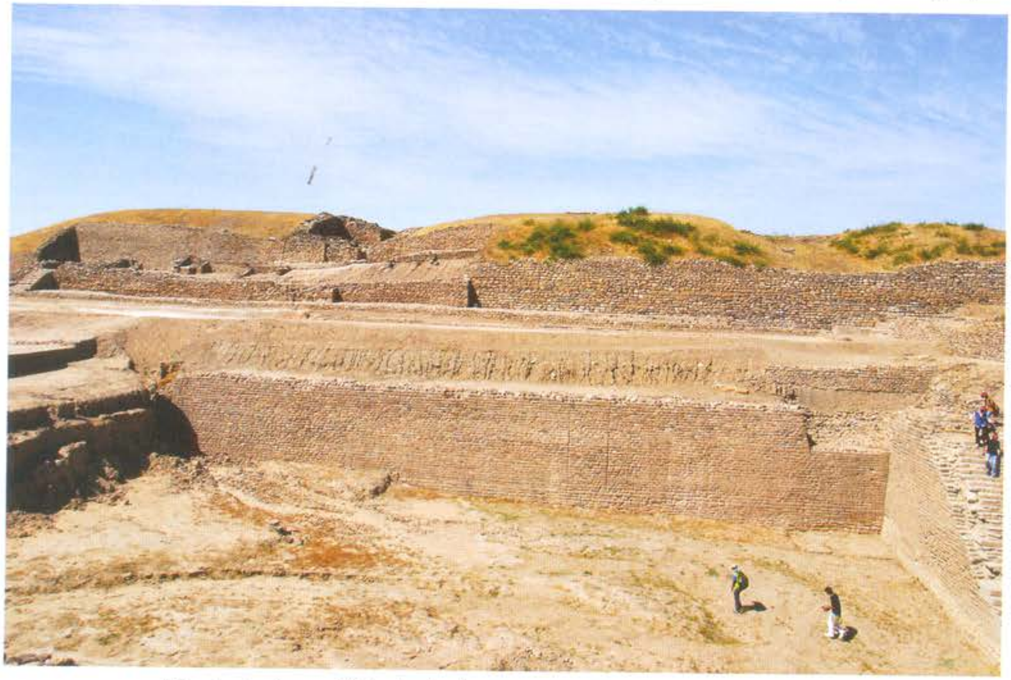

Fig. 4: A view of Dholavira's eastern reservoir (author's photo).

* Ratio 5:2 is that of Dholavira's colossal eastern reservoir[24] (73.5 x 29.3 m, thus with a margin of 0.3%), Fig. 4. It is also reflected, with the same high precision, in 12 rooms of Harappa's "granary", each measuring 15.2 x 6.1 m.[25]

* Ratio 11:4 is that of the secondary rock-cut reservoir "SR3"[26] found to the south of the Dholavira's "castle", 15.5 x 5.65 m, with a high degree of precision (0.2%), Fig. 5.

* Ratio 3:1 is found at Mohenjo-daro's "college" whose average dimensions are 70.3 x 23.9 m.[27]

The above few examples are summarized (with a few more) in Fig. 6. In probabilistic terms, while lower ratios (such as 7:6) could be rejected as a rough approximation of 1 and therefore of no particular significance, the higher we rise in the scale and the less tenable such an explanation will be: the intentional use of specific proportions is indisputable and has not attracted sufficient attention so far. Harappan architects and builders did not believe in haphazard constructions, but followed precise canons of aesthetics based on specific proportions.

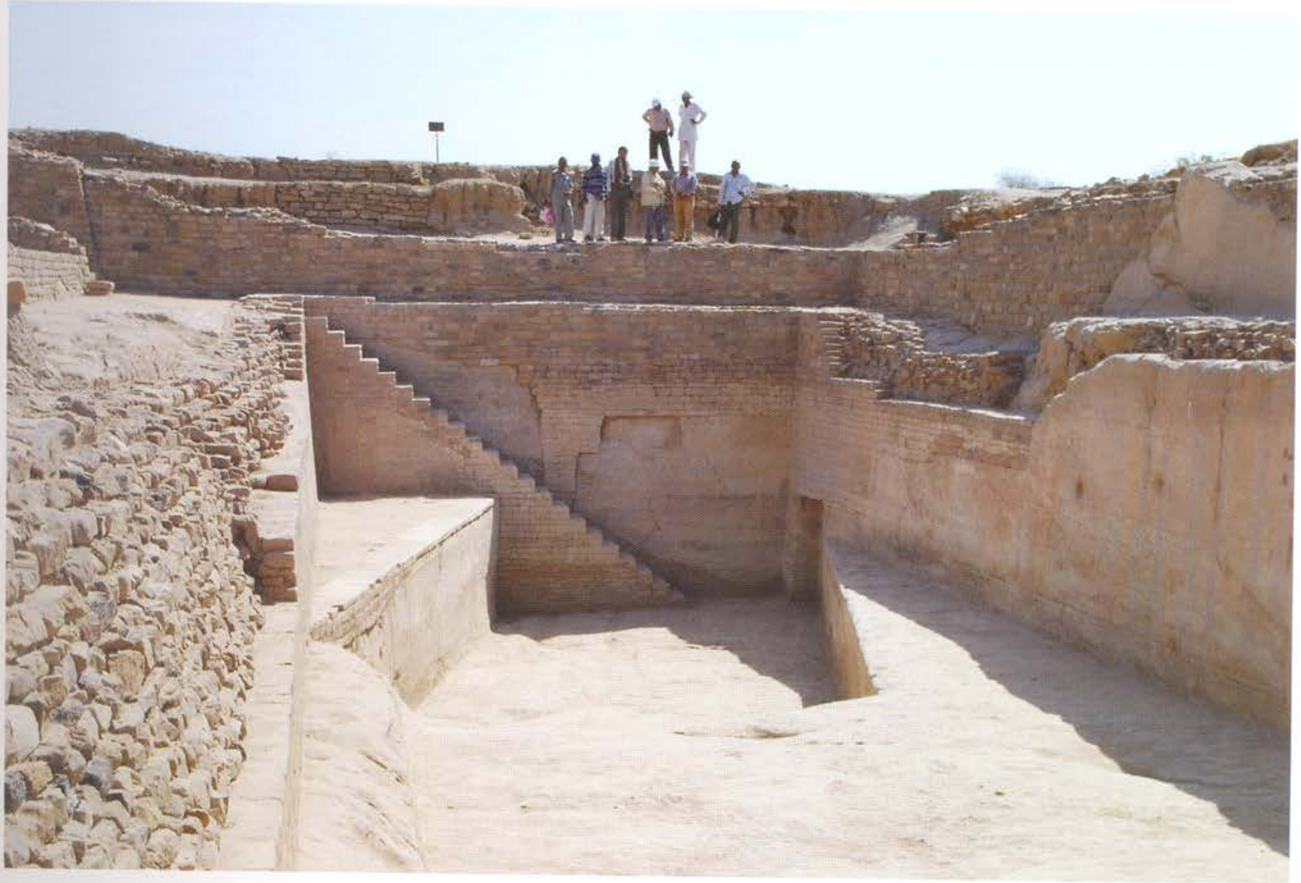

Fig. 5: A view of Dholavira's SR3 southern reservoir (author's photo).

* Ratio 7:2 is that of Dholavira's primary rock-cut reservoir "SR3"[28] mentioned above (33.4 x 9.45 m, thus with a margin of 1%), Fig. 5.

* Ratio 6:1 is reflected not just in Dholavira's ceremonial ground but in Lothal's dockyard[29] (average dimensions 216.6 x 36.6 m).

We can also see that Dholavira's ratios are not exclusive to this site but are part of a broader Harappan tradition of town planning and architecture, whose conceptual foundations remain poorly understood.

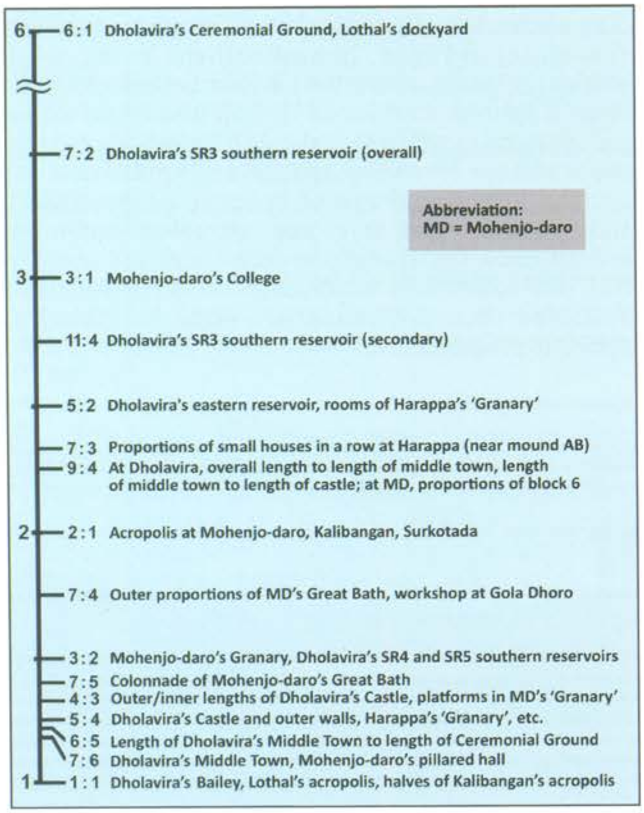
6
6 : 1 Dholavira's Ceremonial Ground, Lothal's dockyard
7 : 2 Dholavira's SR3 southern reservoir (overall)
Abbreviation:
MD = Mohenjo-daro
3
3 : 1 Mohenjo-daro's College
11 : 4 Dholavira's SR3 southern reservoir (secondary)
5 : 2 Dholavira's eastern reservoir, rooms of Harappa's 'Granary'
7 : 3 Proportions of small houses in a row at Harappa (near mound AB)
9 : 4 At Dholavira, overall length to length of middle town, length of middle town to length of castle; at MD, proportions of block 6
2
2 : 1 Acropolis at Mohenjo-daro, Kalibangan, Surkotada
7 : 4 Outer proportions of MD's Great Bath, workshop at Gola Dhoro
3 : 2 Mohenjo-daro's Granary, Dholavira's SR4 and SR5 southern reservoirs
7 : 5 Colonnade of Mohenjo-daro's Great Bath
4 : 3 Outer/inner lengths of Dholavira's Castle, platforms in MD's 'Granary'
5 : 4 Dholavira's Castle and outer walls, Harappa's 'Granary', etc.
6 : 5 Length of Dholavira's Middle Town to length of Ceremonial Ground
7 : 6 Dholavira's Middle Town, Mohenjo-daro's pillared hall
1
1 : 1 Dholavira's Bailey, Lothal's acropolis, halves of Kalibangan's acropolis

Fig. 6: A sampling of ratios found at a few Harappan sites (on a linear scale), generally with a high degree of precision.

Dimensions in Harappan Settlements

Ratios apart, we come across many dimensions of structures in Harappan settlements that can be expressed as integral multiples of our proposed Dholavira unit D = 1.9 m. A few examples are below in Table 4, while Fig. 7 illustrates the case of Mohenjo-daro's acropolis.

While every single dimension cannot be expected to be a whole multiple of D, it is striking enough that so many should turn out to be. This makes a strong case for Dholavira's unit to have been one of the standards in the Harappan world, at least as far as town-planning and architecture are concerned.

Harappan site	Structure	Dimensions in metres	In terms of D = 1.9m	Margin of error (%)
Mohenjo-daro	building in HR area	18.9 x 15.2	10 x 8	0.7, 0.2
	"college"	70.3 (length)	37	0.2
	"block 6"	56.4	30	1%
	"pillared hall"	23 x 27	14 x 12	-
	"First Street"[30]	7.6 (width)	4	0.2
Harappa	"granary"	51.2 x 40.8	27	0.2
	12 rooms of granary	15.2 (length)	8	0.2
	14 houses (mound AB)	17.06 (length)	9	0.4
Dholavira	2 stone columns (castle)[31]	3.8 (apart)	2	0.0
	middle town's major street[32]	5.75 (width)	3	0.7
	reservoirSR1[33]	30.35	16	0.2
	reservoirSR3, primary (width)[34]	9.45	5	0.5
	reservoirSR3, secondary (width)[35]	5.65	3	0.9
	reservoirSR4[36]	11.40 (max. length)	6	-
Chanhu-daro	street[37]	5.68 (width)	3	0.6
Lothal	dockyard	216.6 x 36.6	114 x 19	-

Table 4: Dimensions at various Harappan sites precisely expressed as integral multiples of D = 1.9 m. (The margin of error is included only if the published dimensions are judged precise enough).

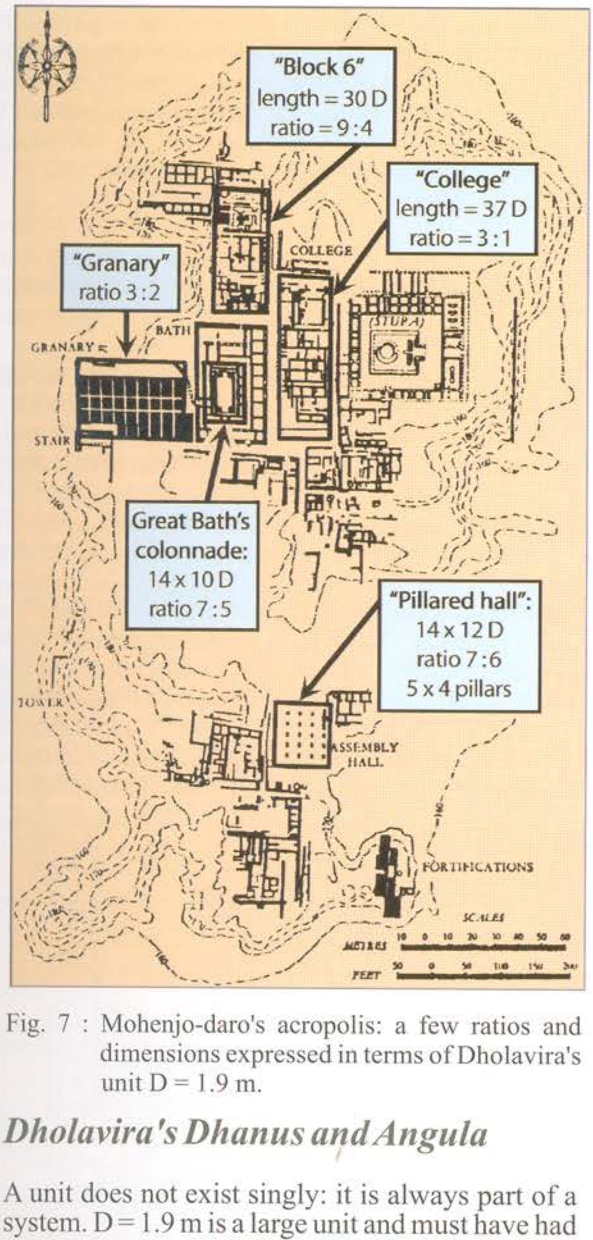

Fig. 7 : Mohenjo-daro's acropolis: a few ratios and dimensions expressed in terms of Dholavira's unit D = 1.9 m.

Dholavira's Dhanus and Angula

A unit does not exist singly: it is always part of a system. D = 1.9 m is a large unit and must have had subunits. In an attempt to figure them out, let us turn to divisions on the three known Harappan scales: those of Mohenjo-daro (6.7056 mm), Harappa (9.34 mm),[38] and Lothal (1.77 mm). The last is evidenced on an ivory scale found at Lothal, which has 27 graduations covering 46 mm. (Both S. R. Rao[39] and V.B. Mainkar erred in dividing 46 mm by 27, when the length must of course be divided by the 26 divisions formed by the 27 graduations).

Dividing D by the first two units yields no clear result. Dividing it by the Lothal unit (1904 by 1.77), we get 1075.7, or, with an approximation of 0.4%, 1080. This last number can be written 108 x 10. In other words, D can be expressed as 108 times 1.77 cm.

Let us pursue this line of inquiry: what is so special about 1.77 cm? First, let us remember that the values of the traditional digit in the ancient world, be it in Egypt, Mesopotamia, China, Greece, Japan or the Roman Empire, fluctuated between 1.6 and 1.9 cm.[40] Ten times the Lothal unit falls in that range. Then, the *Arthashastra* defines a digit (*angula* in Sanskrit) as eight widths of barley grain (2.20.6) or "the maximum width of the middle part of the middle finger of a middling man" (2.20.7).[41] Some eight centuries later, Varahamihira's *Brihat Samhita* (LVIII.2) repeats the first definition; that is the "standard" *angula* of classical India (there are indeed variations in later or regional traditions of iconometry, but they need not detain us here). Most scholars from J.F. Fleet down took the *angula* to be "roughly equating ... ¾th of an inch",[42] that is, 1.9 cm. K.S. Shukla,[43] Ajay Mitra Shastri[44] or A.K. Bag,[45] to quote just a few, endorsed this approximate value. In contrast, the metrologist V.B. Mainkar[46] traced the "development of length and area measures in India" and narrowed the value of the *angula* to 17.78 mm. He was probably the first to suggest that 10 times the Lothal unit, i.e. 1.77 cm, was almost identical to the traditional *angula*.

Moreover, a crude terracotta scale from Kalibangan was submitted to careful scrutiny by the late R. Balasubramaniam, who established that it is based on a unit of 1.75 cm.[47] This is almost the same as the Lothal unit of 1.77 cm.

Let us average the two and call 1.76 cm "A" for *angula*; we then have the following relation: D = 108 A. This is an arresting result, since the concept of "108 *angulas*" is well attested in classical India. For instance, one of the systems of units described in Kautilya's *Arthashastra* (2.20.19) fits very well in the Dholavirian scheme: "108 *angulas* make a *dhanus* (meaning a bow), a measure [used] for roads and city walls."[48] "City walls" is precisely the context in which our unit D was used at Dholavira and elsewhere. We can now propose that "D" also stands for *dhanus*.

The Harappan brick provides us with a degree of confirmation of the Lothal *angula*. In the Mature phase (and occasionally in the Early phase), most bricks follow ratios of 1:2:4 in terms of height-width-length; among several different sizes in this ratio, one dominates by far: 7 x 14 x 28 cm, measured and averaged over numerous samples (as mentioned by Kenoyer[49] and by Rottländer quoting Jansen[50]); the first dimension, 7 cm, is almost exactly 4 Lothal *angulas* (the difference being just 0.5 mm or 0.7%). So the humble brick's dimensions can be elegantly expressed as 4 x 8 x 16A.

Between the *angula* and the *dhanus*, there must have been several important subunits, and elsewhere[51] I attempted to work out a few of them; preliminary findings are that units of 4, 8, 10, 15, 16, 27 and 36 *angulas* were probably in use in Harappan times. However, this requires confirmation through more systematic studies.

Continuity of the Dholavira Scheme of Ratios and Units

The scheme of ratio and units found at Dholavira finds further echoes in historical times. The *Arthashastra* apart, "many [early texts] concentrate on the description of an image of 108 *angulas* in length."[52] The origin of the concept behind the sacred number 108 is probably multiple. It could be simply based on the human body: 108 *angulas* (1.9 m) is the height of a tall man, as specifically mentioned by Varahamihira in his *Brihat Samhita* (68.105).[53] From a different perspective, simple but compelling astronomical considerations behind 108 have been demonstrated by Subhash Kak.[54]

Dholavira's ratios must have been perceived as specially auspicious, otherwise every enclosure might as well have been square. Some of those ratios are still in use in various traditions of Vastu Shilpa. In the sixth century CE, for instance, Varahamihira wrote in his *Brihat Samhita* (53.4 & 5):

> The length of a king's palace is greater than the breadth by a quarter.... The length of the house of a commander-in-chief exceeds the width by a sixth.[55]

These two ratios, 1 + 1/4 and 1 + 1/6, are identical to 5:4 and 7:6 - very precisely Dholavira's most prominent ratios (see Fig. 2). Such a perfect double match appears to be beyond the realm of coincidence.

A recent work by Mohan Pant and Shuji Funo[56] compared the grid dimensions of building clusters and quarter blocks of three cities: Mohenjo-daro, Sirkap (Taxila, early historical, Fig. 8), and Thimi (in Kathmandu Valley, a contemporary town of historical origins). Carefully superimposing grids on published plans of all three cities (their own in the case of Thimi), the authors found that block dimensions measure 9.6 m, 19.2 m (= 9.6 m x 2), or multiples of such dimensions. This, they argue,

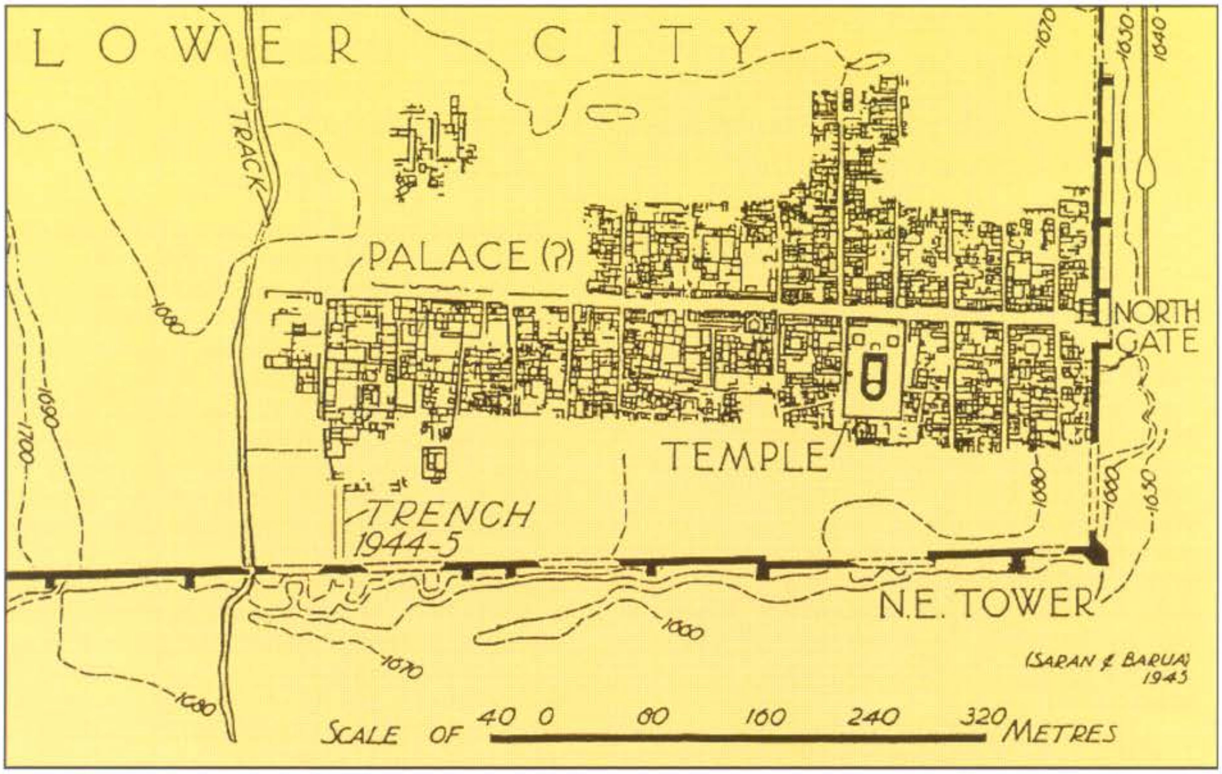

Fig. 8: Plan of Sirkap, one of Taxila's mounds. The blocks of houses are separated by regularly spaced streets, 38.4m apart (=1.92 x 20).

evokes the *Arthashastra's* unit called *rajju*, equal to 10 *dandas*. As regards the *danda*, which has four possible traditional values, the authors choose that of 108 *angulas* as prescribed in the *Arthashastra* (2.20.18-19); it is the same passage which I quoted earlier to define the *dhanus,* and the *danda* is mentioned in it as another name of the *dhanus*: for our purposes, the two terms are identical.

Pant's and Funo's unit of 1.92 m differs from mine of 1.9 m by just 1% ; in both cases, the unit was equated 108 *angulas*. Their work thus lends support to my suggestion that such concepts survived the collapse of Harappan urbanism and re-emerged in Kautilya's canons of urbanism. Is this so surprising, when we already know that the Harappans' weight system, metallurgical, agricultural and craft techniques did live on, apart from numerous religious symbols and practices?[57]

We get further confirmation of such continuity from a case study of the Delhi Iron Pillar (Qutub Minar complex) by R. Balasubramaniam,[58] who applied to it the Harappan *dhanus* and *angula* I had proposed and found they expressed the pillar's dimensions with unexpected harmony (Fig. 9): its total length of 7.67 m, for instance, is precisely 4 D; its diameter, 36 *angulas* at the bottom, shrinks to 24 *angulas* at ground level, finally to taper off at 12 *angulas* at the very top. If this were not enough, the ratio between the pillar's entire length (7.67 m) and the portion above the ground (6.12 m) is 5:4, verified to 0.2% - again, Dholavira's master ratio. This bears out once again that Harappan ratios and linear units survived the collapse of the Indus cities and passed to those of the Ganges Valley. Balasubramaniam applied the same units with excellent results to engineered caves of the Mauryan period[59] and to the Taj Mahal complex,[60] opening a new line of inquiry in classical Indian metrology.

Harappan and Classical Concepts

On a cultural level, the presence of carefully proportioned fortifications as at Dholavira might be as much a specific cultural trait as pyramids are to Egypt or ziggurats to Mesopotamia. Here, instead of erecting colossal buildings, enormous energy was spent on defining spaces: the space of the rulers and administrators (the acropolis) and the spaces for other classes of citizens. Demarcating was a vital need not for defence, but for self-definition: fortifications probably stood for authority and segregation, as Piotr A. Eltsov has recently argued too.[61]

But there may also be deeper motives at work: ratios and units apart, we can discern a few important principles underlying Dholavira's fascinating harmony, in an almost Pythagorean sense of the term. More work and data are needed to bring out those principles securely, but I proposed elsewhere[62] that the Vedic principle of *addition of a unit* is at work here: 5:4 should be read as "one unit plus one fourth", and the key ratio of 9:4, for instance, is nothing but 5:4 plus one unit. This addition to the unit of a fraction of itself can also be seen as a process of expansion, of auspicious increase symbolizing or inviting prosperity. Thus the *Manasara*, a treatise of Hindu architecture, applies this process when it specifies (35.18-20) that "the length of the mansion [to be built] should be ascertained by commencing with its breadth, or increasing it by one-fourth, one-half, three-fourth, or making it twice, or greater than twice by one-fourth, one-half or three-fourths, or making it three times."[63] The outcome is a series of ratios: 5:4, 3:2, 7:4, 2:1, 9:4, 5:2, 11:4, 3:1. Since we found all these ratios at Dholavira or other Harappan settlements, it is tempting to assume that the concept behind such auspicious ratios was the same in Harappan times.

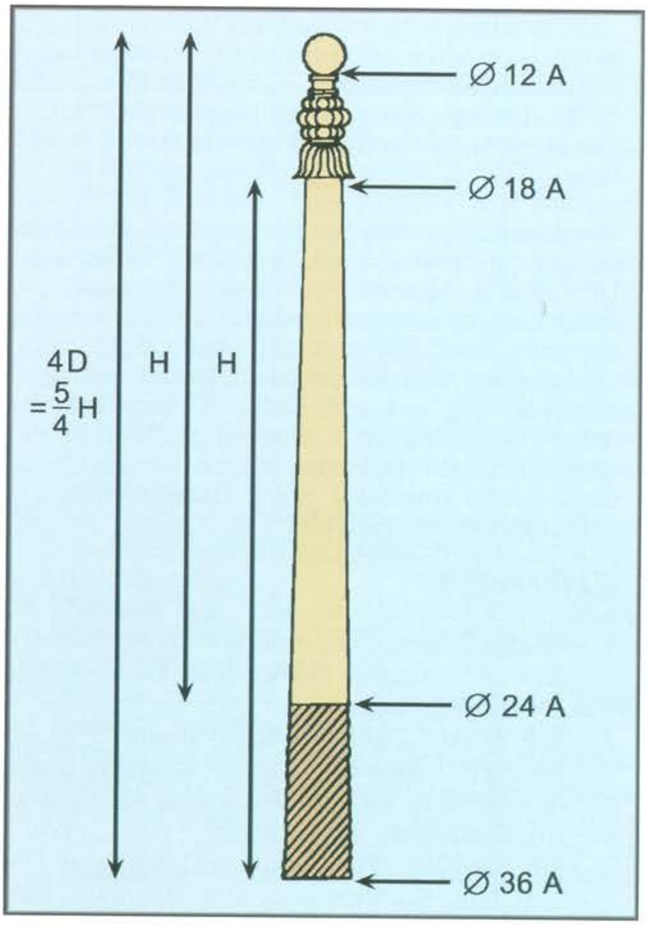

Fig. 9: A sketch on the Delhi Iron Pillar with the main dimensions expressed in terms of D = Dholavira's *dhanus* (1.9 m) and A = Dholavira's *angula* (1.76

Also found at Dholavira is another Vedic principle, that of *recursion* or repetition of a motif.[64] Thus the "castle" and the overall city share the same ratio (5:4), and 9:4 defines the expansion from the length of the "castle" to that of the middle town, and again to that of the lower town.

The thread connecting those principles was anticipated by astrophysicist J. McKim Malville, who saw in Dholavira's features "the apparent intent ... to interweave, by means of geometry, the microcosm and the macrocosm".[65] To the ancient mind, the concept of sacred space was inseparable from the practice of town-planning and architecture. Dilip Chakrabarti echoes this in his recent observation: "The ideals of ancient Indian town planning seem to run deep through the concepts embedded in the Harappan cities like Mohenjodaro and Dholavira."[66]

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Social Inclusiveness of Indian Science Centres and Museums – A Snapshot through Case Studies (Part-I)

Subhabrata Chaudhuri

The science centres and museums in India have become a part of the social fabric in disseminating knowledge of science and technology to the people in a non-formal manner. Need for this kind of non-formal education is becoming essential with the passage of time and has become one of the most important sources of information for the people.

Science centres and museums play a significant role in combating social exclusion. In partnership with other agencies, these institutions lead the way for the whole cultural sector in pursuing inclusive agenda. It is ironic that this role, despite its long pedigree, is not the one which is widely known. Part of this explanation is that science centres and museums have not been vociferous in promoting this aspect of their work.

Social Inclusion is at the core of the system of values of the science centres and museums in India. It is a key driver in all decisions relating to strategic vision, policies and programmes in such institutions. A study is presented here in two parts to highlight the current scenario, based on survey of 41 Indian science centres and museums in respect of social inclusiveness in different perspectives.

Objectives of the Study

This study attempts to address certain questions in the present context:

- In our effort to make our centres more modern and more attractive, are we leaning towards more exotic and expensive gizmos?
- Are we making them stunning beauties by excluding social activism as the mundane redundancy?
- Are we creating environments and programs skewed only to the able, empowered and affluent?
- Are we friendly enough to the differently able, to people with special needs or to special ethnic, economic or language groups?
- And above all, are the society and locality supporting a centre being led to any kind of empowerment by the programs and presentations of the centre?

The task, we anticipate, would be daunting and may take significant feedback-oriented reshaping in course of our investigation and introspection. As a first order study, we intend to focus on exploring how a museum/ centre is reinventing itself as an agent of social inclusion and to comprehend what is the type of operational model that these centres are following to occupy the rapidly changing landscape of social inclusion policies. This is followed up by intensive auditing in a select group of science centres and museums with the help of a specially designed audit checklist.

In the second part, we would also like to investigate through questionnaire survey and statistical analysis as to what extent the concept of social inclusion would require a new approach by museums and in what ways these institutions could contribute towards inclusion policies.

Accessibility: Big Issues for the Social Inclusion Practices in Science Centres and Museums

Access is defined as something that is made possible when physical, cultural, social, financial, intellectual, psychological and emotional barriers are removed or reduced. All people have the right to freely participate in the cultural life of the community, to enjoy the arts and to share scientific advancement and its benefits. This is stated in the 'Universal Declaration of Human Rights'. Merely setting up of museums without ascertaining whether the services and resources of these institutions would be utilized by the people does not justify the social role of public museums, especially in a democratic country like India, where the government owns a majority of museums. The museum resources must be accessible to all.

To eliminate barriers and ensure equality of access, accessibility has a number of forms. Museum accessibility can be classified into five types- physical, sociocultural, economic, sensory and intellectual/ learning. With more and more such institutions going virtual and web-based, digital accessibility is another new classification that has emerged now.

Social Inclusion steps by Indian Science Museums and Centres

In order to understand the social exclusion and to promote inclusion in science centres and museums, it is useful to briefly identify the role that science centres and museums can play in tackling these issues. For some people, the potential role of museums is confined to broadening of their audience profile. In fact, "Museums for all" psychology acknowledges that efforts are required to be made to identify and remove the barriers that exist to exclude many groups from museums.

Barrier-free Science Centre / Museum

Intellectual acceptance of the exhibition content to all strata of society is important for science centres/ museums. It is also necessary that the exhibits and collections are to be made physically accessible to all the visitors. Different initiatives have been taken to combat physical exclusion within the science centres / museums in India.

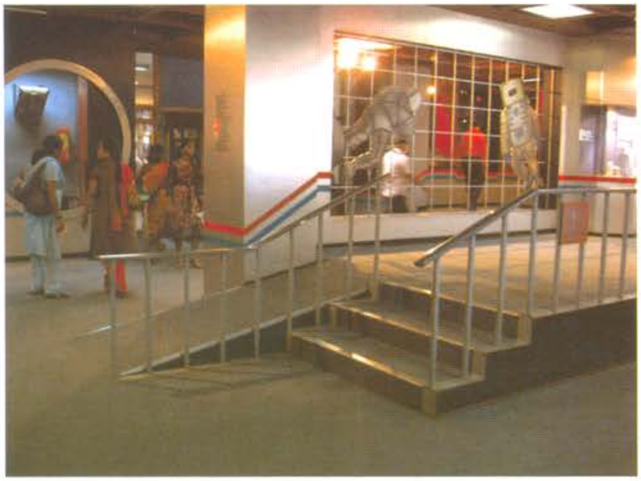


Fig. 1. Accessible Exhibition areas at VITM.

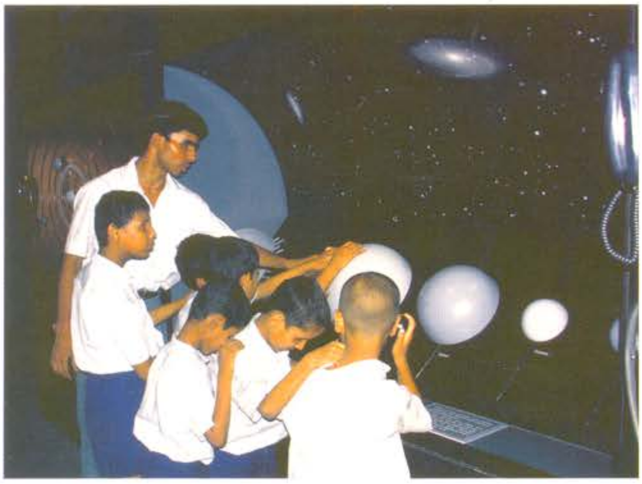
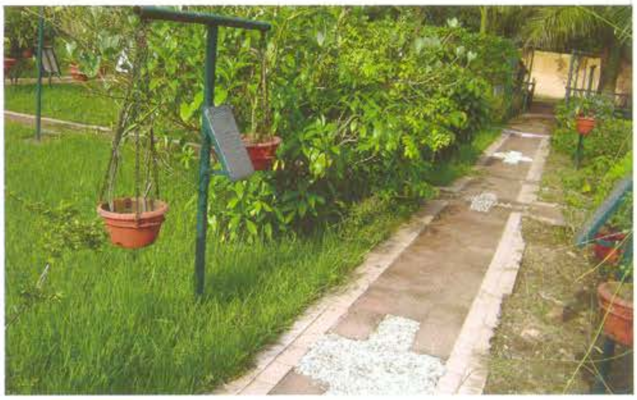


Fig.2. Accessible Exhibit content 'World in Darkness' gallery at BITM.

Ramps have been provided within the gallery for easy maneuvering of wheelchair bound visitors. Exhibit labels have been provided in more than one sensory channels. In Birla Industrial & Technological Museum (BITM), Kolkata, a special exhibition has been introduced for the visually challenged visitors, in Regional Science Centre (RSC), Guwahati, a medicinal plant garden with special pathways and information labels in Braille is provided for the visually impaired.



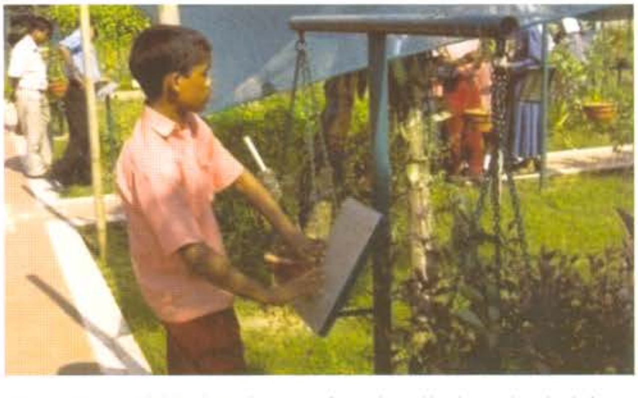


Fig. 3&4. Pebbled pathways for visually impaired visitors with labels in Braille at 'Medicinal Plant Garden' at RSC, Guwahati.

Bridging the gap in understanding

In India, science centres and museums organize different programmes and activities round the year in dispelling widespread superstition about celestial events or diseases. These institutions also provide a platform for social interactions on scientific issues that encourage and facilitate better understanding of science.

It is often argued in different contexts that cultural institutions can act as the trusted incubators for change by providing a variety of information sources, offering challenging and participatory experiences. But significantly, science centers facilitate visitors to engage topics on their own terms in their own capacity as expert informants, as opposed to the old pedagogic paradigm as authorities. In addition to the evidence of the knowledge and understanding development, considerable instances have been collected from visitors to science centers practicing and developing skills of exploration, observation, interpreting data, sharing ideas, and other skills directly related to scientific belief.

Fig. 5. Creating scientific temper by demystifying various myths and superstitions prevalent in the society (scene from Kurukshetra Panorama and Science Centre).

Fig. 6. Visitors from a special religious group in 'Mock up Coalmine' at BITM.

Reaching out to the Target groups

The school students happen to be the prime target group for a Science Centre/Museum. Science Centres in India have taken up various initiatives like Mobile Science Exhibitions, Creative Ability Centre, Science Fairs, Science Drama, Science Seminars and so on to reach out to this specific group.

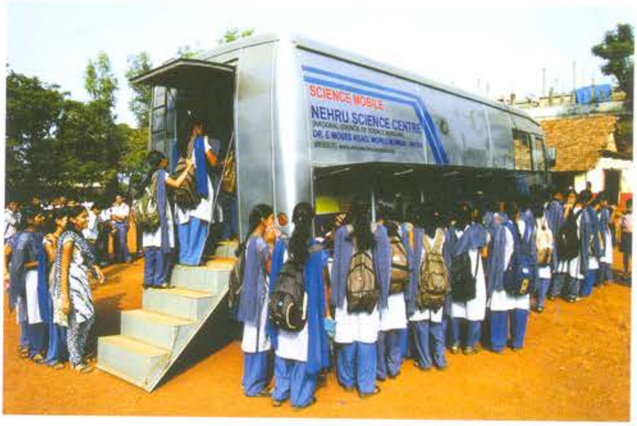


Fig. 7. Mobile Science Exhibition programme in a School.

Fig. 8. Summer Hobby Camp.

Fig. 9. Science fair.

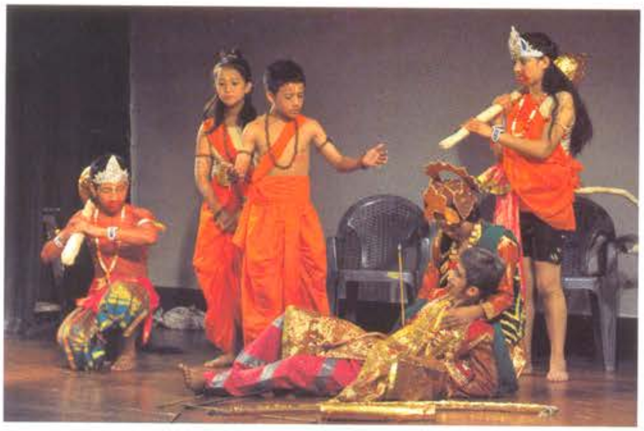


Fig.10. Preparation for Science Drama competition.

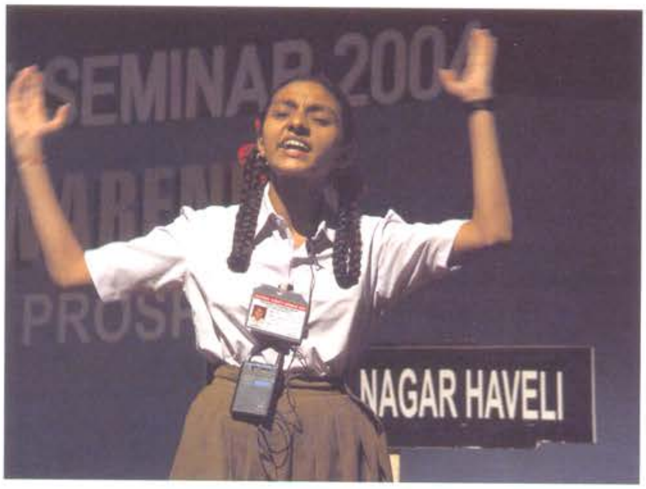


Fig.11. Presentation of a participant during National Science Seminar.

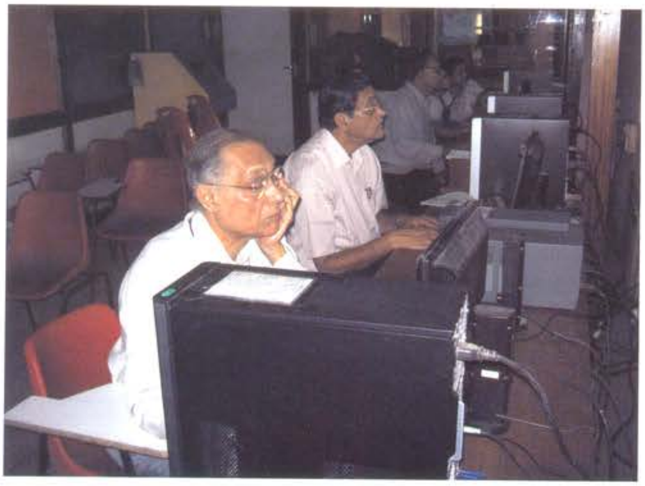


Fig.12. Computer training for Senior citizens and women at Regional Science Centre, Guwahati.

Engaging various social groups

Indian Science Centres have taken necessary steps to include all strata of society to ensure inclusiveness. Computer training programmes for senior citizens and women, various activites for physically challenged children, programmes for personal development and programmes to combat the problem of unemployment etc. are examples of some of these initiatives.

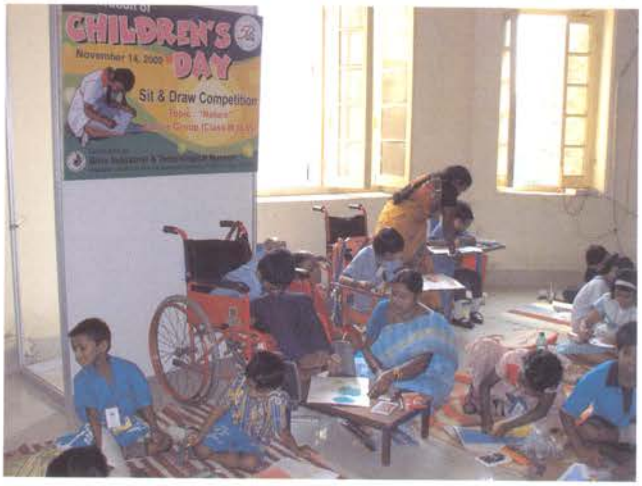


Fig.13. Sit & Draw competition for physically challenged children at BITM, Kolkata.

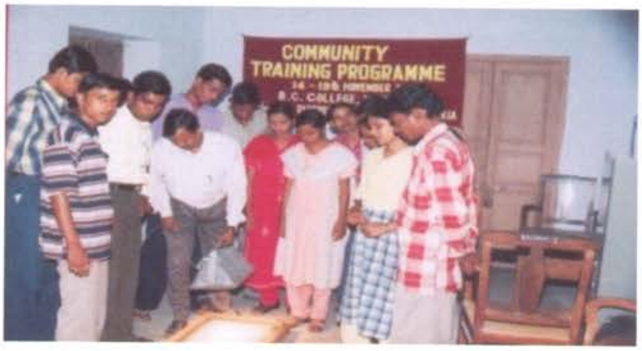


Fig. 14. Community Training programme at District Science Centre (DSC), Purulia.

Social Inclusion Audit Checklist - Is Your Science Centre / Museum 'Socially Inclusive'?

Science centres and museums were created on the basis of this philosophical model of inclusion almost half a century back in this country. And it is yielding some results. However the mode of operation vis-à-vis ground realities is required to be studied as well.

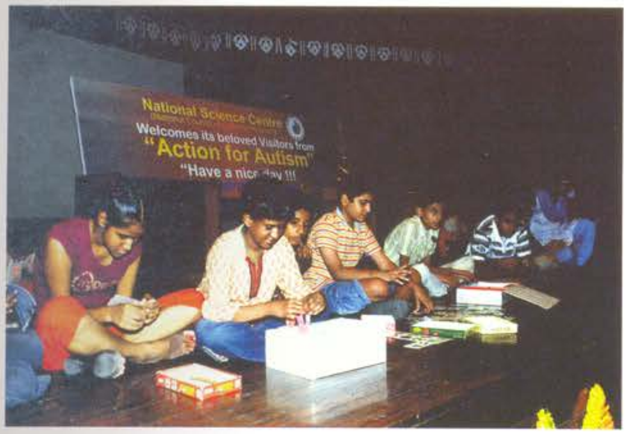


Fig.15. Programme for Autistic children at National Science Centre (NSC), Delhi.

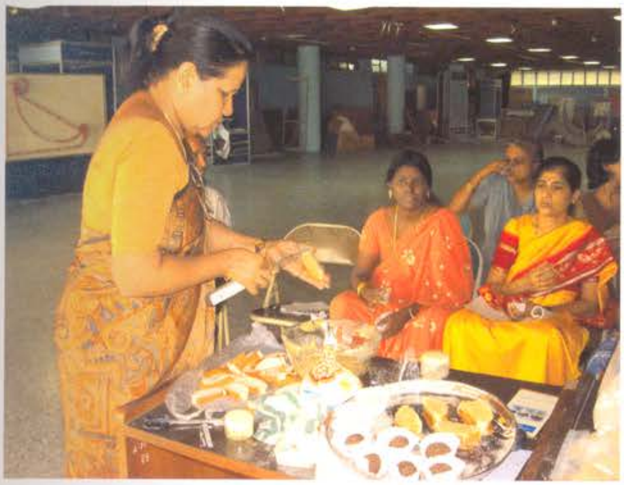


Fig.16. Professional training to combat unemployment at Visvesvaraya Industrial & Technological Museum, Bengaluru.

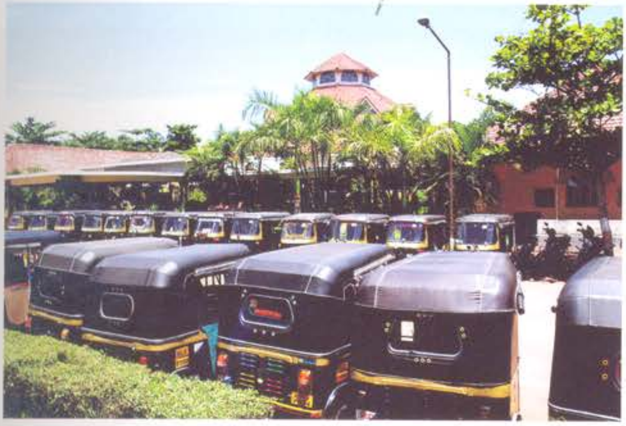


Fig.17. 'Word-of-Mouth' – a publicity campaign through auto drivers initiated by Regional Science Centre, Calicut.

As indicated in the preceding sections, 'accessibility' is considered as the first step towards social inclusion of a Science Centre / Museum. A rating is adopted here using a checklist of 'Social Inclusion Audit'. This checklist, as furnished in the Appendix-A, is devised taking into consideration the 'Guidelines and Space Standards for Barrier-Free Built Environment for Disabled and Elderly Persons' of Central Public Works Department (1998), People with Disability Act 1996 of Government of India, 'Smithsonian Guidelines for Accessible Exhibition Design', 'Open to All? Science Centres and Museums in the UK: Strategies for Social Inclusion' by Anwar Tlili of Centre for Informal Learning Schools, King's College, London, the 'Museums and Social Inclusion, The GLLAM Report' (Group for Large Local Authority Museums, October 2000), research undertaken by the Research Centre for Museums and Galleries (RCMG), Department of Museum Studies, University of Leicester. In the later stage, field survey was carried out in a select group of science centres and museums.

Inclusion Audit in Science Centres / Museums – A Report

Survey outcome for BITM, Kolkata

BITM secured 26 x 2.5 = 65 out of 100

Accessible. More steps need to be taken for greater physical accessibility rather than intellectual accessibility.

A glimpse of accessibility/inaccessibility of BITM, Kolkata

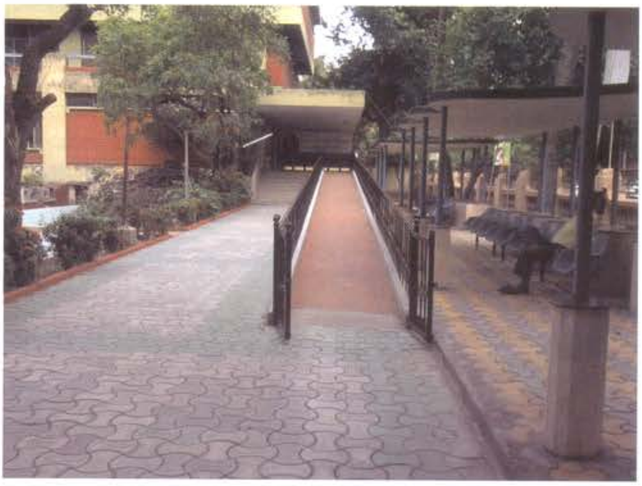
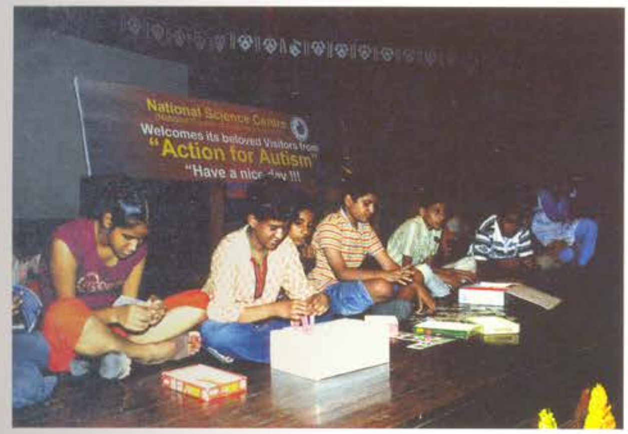


Fig.18. Ramp - as accessibility sign for wheelchair bound visitors.



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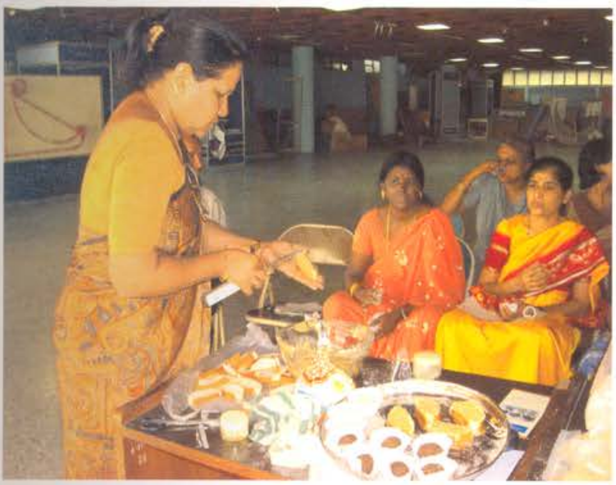

Fig.16. Professional training to combat unemployment at Visvesvaraya Industrial & Technological Museum, Bengaluru.

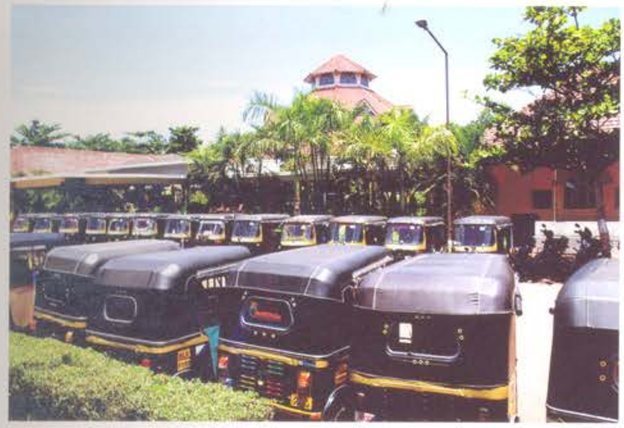

Fig.17. 'Word-of-Mouth' – a publicity campaign through auto drivers initiated by Regional Science Centre, Calicut.

As indicated in the preceding sections, 'accessibility' is considered as the first step towards social inclusion of a Science Centre / Museum. A rating is adopted here using a checklist of 'Social Inclusion Audit'. This checklist, as furnished in the Appendix-A, is devised taking into consideration the 'Guidelines and Space Standards for Barrier-Free Built Environment for Disabled and Elderly Persons' of Central Public Works Department (1998), People with Disability Act 1996 of Government of India, 'Smithsonian Guidelines for Accessible Exhibition Design', 'Open to All? Science Centres and Museums in the UK: Strategies for Social Inclusion' by Anwar Tlili of Centre for Informal Learning Schools, King's College, London, the 'Museums and Social Inclusion, The GLLAM Report' (Group for Large Local Authority Museums, October 2000), research undertaken by the Research Centre for Museums and Galleries (RCMG), Department of Museum Studies, University of Leicester. In the later stage, field survey was carried out in a select group of science centres and museums.

Inclusion Audit in Science Centres / Museums – A Report

Survey outcome for BITM, Kolkata

BITM secured 26 x 2.5 = 65 out of 100

Accessible. More steps need to be taken for greater physical accessibility rather than intellectual accessibility.

A glimpse of accessibility/inaccessibility of BITM, Kolkata

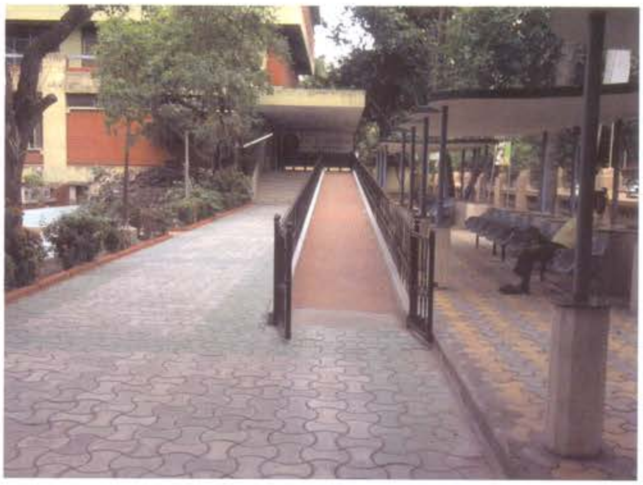

Fig.18. Ramp - as accessibility sign for wheelchair bound visitors.

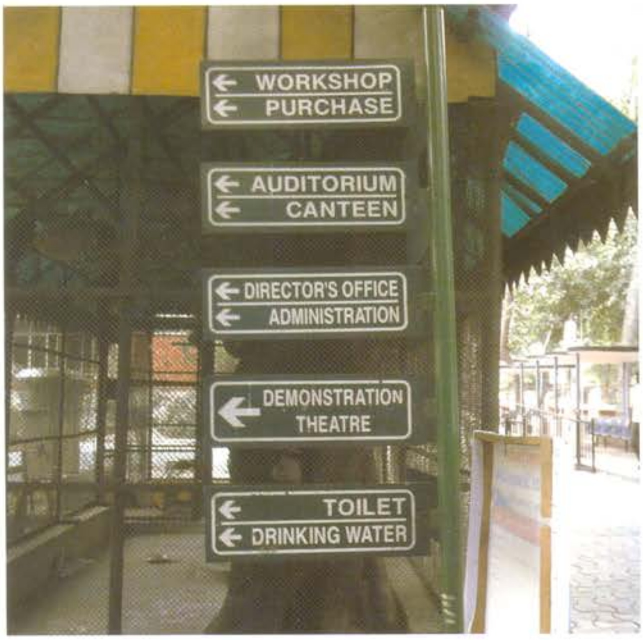

Fig.19. 'Signage' at strategic locations but absence of symbolic representations.

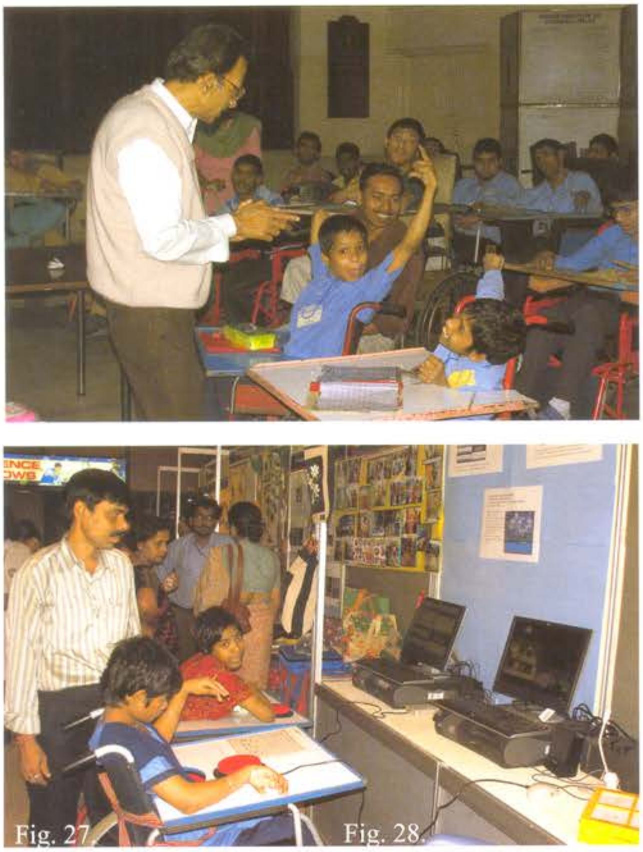

Fig. 20&21. Different programmes are conducted targeting special groups.

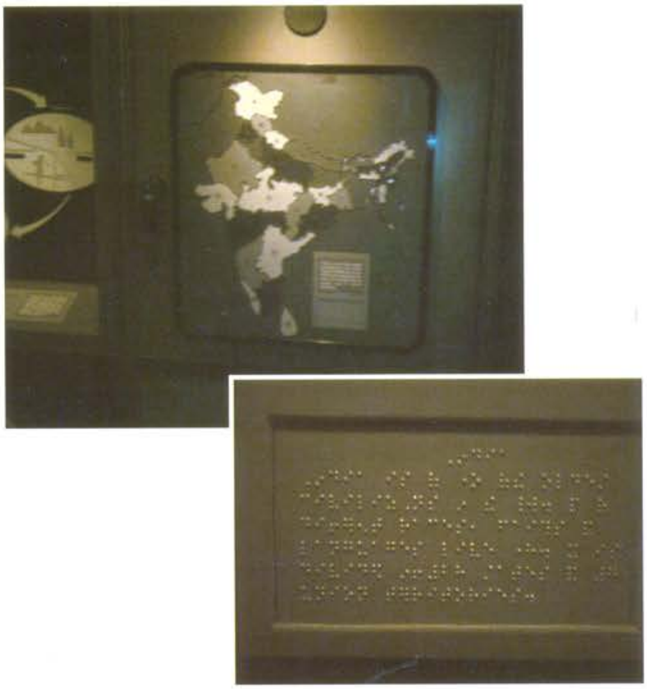

Fig. 22. A glimpse of an exhibition specially designed for visually impaired.

Survey outcome for Science City, Kolkata

Science City, Kolkata secured 29 x 2.5 = 72.5

Accessible. More initiatives need to be taken for intellectual accessibility.

A glimpse of accessibility/inaccessibility for Science City, Kolkata

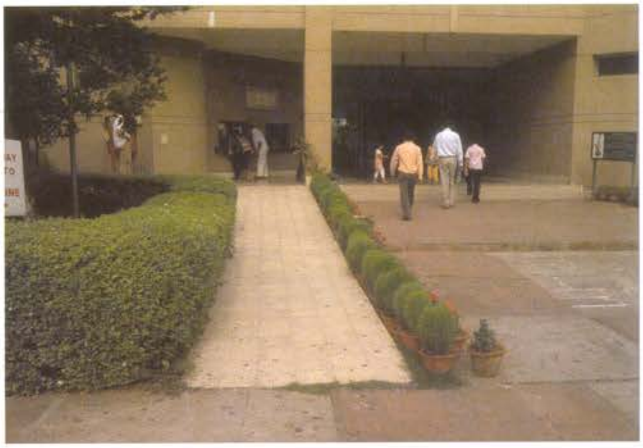

Fig. 23. Ramp at the entrance of Dynamotion Hall.

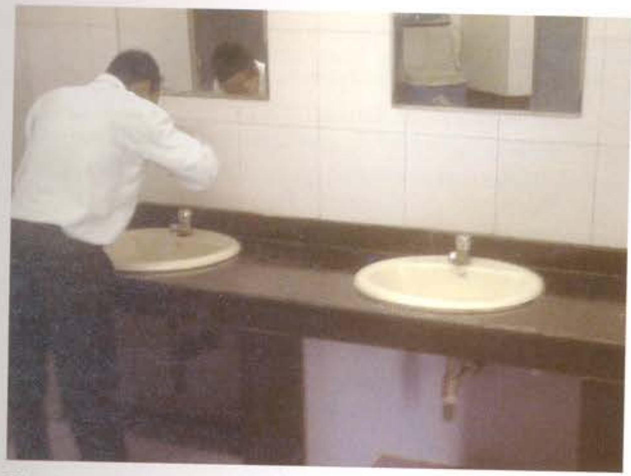

Fig. 24. Accessible water faucets.

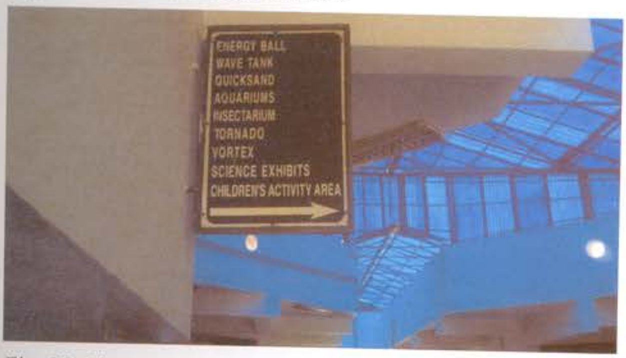

Fig. 25. Signage at strategic locations.

Survey outcome for Indian Museum, Kolkata

(Partial information available)
Indian Museum secured 7 x 2.5 = 17.5 (out of 72.5)

Inaccessible. To the large section of visitors, this museum is intellectually as well as physically inaccessible. Considering the importance of a 'Natural History Museum', major accessibility measures need to be taken.

A glimpse of accessibility/inaccessibility of Indian Museum

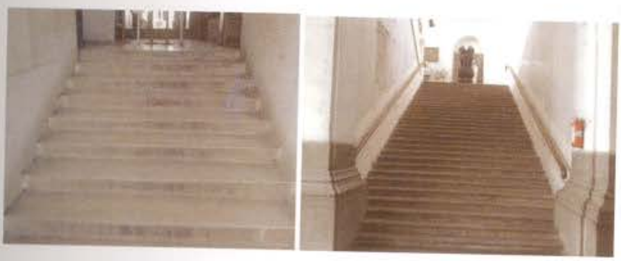

Fig. 26 & 27. No ramp is found at entry or exit.

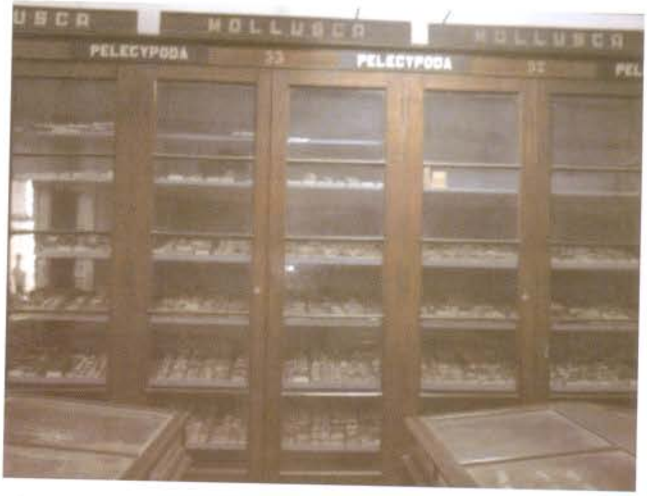

Fig.28. Poor Illumination, visually inaccessible artifacts, samples etc.

Fig.29. Glare from exhibit cabinets etc.

Results of Social Inclusion Audit for the Select Group of NCSM Science Centres and Museums

Based on the forty parameters as per the checklist (given in Appendix-A), ratings of some of the science centres and museums in terms of accessibility have been evaluated. The following are the results:

Name of the Centre	Accessibility Score
Regional Science City, Lucknow	33 x 2.5 = 82.5
National Science Centre, Delhi	31 x 2.5 = 77.5
District Science Centre, Purulia	28 x 2.5 = 70
North Bengal Science Centre, Siliguri	27 x 2.5 = 67.5
Srikrishna Science Centre, Patna	25 x 2.5 = 62.5
Arunachal Pradesh Science Centre	25 x 2.5 = 62.5
Regional Science Centre, Bhopal	23 x 2.5 = 57.5
Visvesaraya Industrial & Technological Museum, Bengaluru	23 x 2.5 = 57.5
Digha Science Centre	22 x 2.5 = 55
Regional Science Centre, Bhubaneswar	20 x 2.5 = 50
Nehru Science Centre, Mumbai	20 x 2.5 = 50
District Science Centre, Dhenkanal	10 x 2.5 = 25
Bardhaman Science Centre	8 x 2.5 = 20

Conclusion

In Part-I of this article, an attempt has been made to ascertain the accessibility scenario of Indian science centres and museums as a part of studying social inclusiveness of this sector. In this phase, we undertook field studies, went through the statistics in respect of conducting different activities both inside and outside the institutions and finally initiated social inclusion audit in the select group after devising a checklist based on well-known standard practices. In Part-II, we propose to analyse the statistical data collected through questionnaire surveys in 41 institutions (including planetariums and natural history museums) and draw inference on the basis of this analysis.

Acknowledgement

The author acknowledges the contribution of all heads of the science museums & centres of the country and the members of their teams, and other participating institutions who helped by way of responding to the questionnaire and cooperating in other surveys as a part of this study.

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Appendix - A

Social Inclusion Audit (Checklist)

Sl. No.	Measure	Yes	No
Physical Accessibility Measures			
1.	**Provision of wheel chairs for physically challenged visitors**		
2.	**Provision of suitable ramps in the entrance and exit for the wheelchair bound and visually challenged visitors** (A ramp with 1:12 gradient and handrails on both the sides should be provided)		
3.	**Provision of suitable ramps in the galleries for the wheelchair bound and visually challenged visitors**		
4.	**Provision of lifts for physically and visually challenged visitors**		
5.	**Guiding/Warning Floor Material for persons with impaired vision** *Line-type blocks indicate the correct path/route to follow.* *Dot-type blocks provide warning signals, to screen off obstacles or other hazards, to discourage movement in an incorrect direction and to warn of a corner or junction.* *Warning strip should be placed 300mm at the beginning and end of the ramps, stairs and entrance to any door.*		
6.	**Sufficient space around the water faucets and toilets to make it easily accessible for wheelchair users** (Depending on the type of water faucet, a space about 700 mm high and 350 mm deep under the faucet to be provided)		

7.	**Signage being provided at strategic locations regarding all the amenities**		
8.	**Floorwise key plans and Floor signage being provided for persons with short stature or wheelchair bound**		
9.	**Braille information plates being provided**		
10.	**The circulation route within the exhibition accessible according to the following requirements** i) The circulation route must be at least 915 mm/36 inches wide for one-way wheelchair ii) For two-way routes, the minimum width is 1525 mm/60 inches		
11.	**The circulation route clearly defined, well-lighted, and easy to follow and provision of sufficient light on objects to make them visible to all visitors** (unless the light level does substantial damage to the objects)		
12.	**Nearby seating arrangement in a corridor or in an adjacent gallery space**		
13.	**Exhibit cabinets / cases posing safety hazards to visitors**		
14.	**The colors and patterns of exhibition floor surfaces giving accurate information about the depth, height, and condition of the floor surface**		
15.	**Assistive listening systems provided in all public programme spaces**		
16.	**Both visual and audible fire alarm systems provided**		
17.	**Provision of fully accessible emergency egress from the exhibition spaces**		
18.	**Items in exhibitions (e.g. artifacts, graphics, props) visually accessible to people** i) Mounting small items at a height not more than 1015 mm (40 in.) above the floor ii) Constructing the top of a case at a maximum of 915 mm		
19.	**Items essential to the exhibition's main theme accessible to people by tactile examination (e.g. touching artifacts, reproductions, models) and/or comprehensive audio description**		
20.	**All exhibit cabinets / cases are within the viewing access to people who are short or seated as well as to those who are standing**		
21.	**Colors of / within exhibit cabinets / cases provide clear visual access to items inside**		
22.	**Colors for labels have a high contrast between text and background**		
23.	**Provision of sufficient light on labels to make them readable by all visitors and glare from cabinets / cases eliminated for those who are seated as well as for those who are standing**		
24.	**Controls for and operation of all interactives to be accessible and usable by all visitors**		

Sl. Nos. 1 to 24 are conforming to the 'Guidelines and Space Standards for Barrier-Free Built Environment for Disabled and Elderly Persons' of Central Public Works Department (1998) & People with Disability Act 1996 of Government of India and 'Smithsonian Guidelines for Accessible Exhibition Design'

Intellectual Accessibility Measures			
25.	**Exhibit content accessible at multiple intellectual levels** (Simplified multilingual labels without jargons have been provided etc.)		
26.	**Exhibit content presented through more than one sensory channels** (Braille and voice over version of these labels to be provided etc.)		

Sl.Nos. 25 and 26 are conforming to the 'Smithsonian Guidelines for Accessible Exhibition Design'

Digital Accessibility Measures			
27.	**Instructions for proper use of inter-actives to be accessible to all visitors (like font size flexibility)**		
28.	**Inter-actives and audiovisuals which do not have soundtracks with labels for people with low hearing capacity**		
29.	**Audiovisual programs and computer interactives that present information with images and texts are audio described also**		

Sl. Nos. 27 to 29 are conforming to the 'Smithsonian Guidelines for Accessible Exhibition Design'

Emotional Accessibility			
Making Science Relevant and Inclusive			
30.	**Successfully establishing relevance of science to everyday life and to the society**		
31.	**Maintaining a balance between relevance to non-traditional audience and the specialist**		
Working with Schools as a part of socially inclusive practices			
32.	**Supporting and subsidizing school trips as well as doing some outreach programmes at schools by supporting the curriculum**		
33.	**Focusing support and resources on schools from areas with large proportions of minority, ethnic and low income groups**		
Lifelong Learning			
34.	**Conducting training programmes on basic literacy and technical skills for different groups (Young, Women, Senior Citizens and marginalized groups like SC, ST, etc.)**		
Outreach as social inclusion			
35.	**Conduct outreach programmes (without any marketing agenda)**		

Sl. Nos. 30 to 35 are conforming to the 'Open to All? Science Centres and Museums in the UK: Strategies for Social Inclusion' by Anwar Tlili of Centre for Informal Learning Schools, King's College, London

Economic Accessibility			
Programme for Groups with Special Needs			
36.	**Conducting programmes targeting groups with special needs**		
Programme for personal growth & community empowerment			
37.	**Conducting programmes for personal growth & community empowerment**		
Programme for Financial Inclusion			
38.	**Conducting programmes for tackling the problem of unemployment**		
39.	**Provision of special benefits for the lower income groups or the underprivileged for entering the centre/museum**		
Programmes for Tackling Crime			
40.	**Conducting programmes for tackling crime**		

Sl. Nos. 36 to 40 are conforming to the 'Museums and Social Inclusion The GLLAM Report' (Group for Large Local Authority Museums, October 2000), research undertaken by the Research Centre for Museums and Galleries (RCMG), Department of Museum Studies, University of Leicester.

NB: Each parameter has been assigned equal weight of 2.5, considering the fact that the total weight of all the forty (40) parameters of this study would be 100 (40x2.5=100).

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- Science Centre/Museum as non-formal science learning institutions
- New galleries and exhibitions
- Innovative exhibits and presentations
- New outdoor science expositions and outreach science activities
- Contemporary and significant developments in science and technology
- History of science and technology with special reference to India
- Science and Society
- Visitor's studies in science center/museum
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